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FINAL PROJECT REPORT

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy‐Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End‐Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Affordable Multifamily Zero Energy New Homes is the final report for the project (contract number 500‐04‐023, conducted by Global Green USA. The information from this project contributes to PIER's Buildings End Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916‐327-1551.

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Abstract

The California Energy Commission has set aggressive targets for the development of zero net energy buildings over the coming decades. In order to assess the technical and financial viability of zero net energy building designs, the Commission developed a Zero Energy New Homes (ZENH) research program. Under this program, the Commission contracted with Global Green USA to partner with a pair of non-profit housing developers to build two Zero Energy Multifamily Affordable housing projects in San Diego County. The first project, Solara, opened in Spring of 2007, and the second project, Los Vecinos, opened in Spring of 2009.

On energy performance, the projects attempted to meet three key criteria: (1) perform 25% better than Title 24 (2005) California energy code; (2) have a 70% reduction in electricity costs for the occupants compared to standard housing, (3) have summer peak electrical demand of 1 kW or less per housing unit. With respect to first costs, the projects attempted to spend less than $5,000 additional dollars per housing unit, after rebates and incentives. The purpose of having both financial and technical goals was to explore not only the performance feasibility of zero energy affordable multifamily housing but also to develop a replicable business model for other affordable housing developers could follow statewide.

Community HousingWorks was the developer of Solara. Solara exceeded 2005 Title 24 by approximately 15% and 2001 Title 24 by 40%, reduced electric utility costs by 62%, and had a peak summer demand of well below 1 kW throughout the year. Solara is a net exporter of electricity at the time of the local utility peak for nine out of twelve months of the year, including the annual system peak in the summer. Wakeland Housing and Development Corporation was the developer of Los Vecinos. Los Vecinos was 43% better than 2005 Title 24, reduced electric utility costs by 62% and had a summer peak demand of well below 1 kW throughout the year. Los Vecinos is a net exporter of electricity during the four hottest months of the year.

Both projects achieved these performance results with additional first costs of significantly less than the $5,000 goal. Solara spent an additional $2,102, of which $656 was for energy efficiency measures and $1446 was for on-site generation. Los Vecinos spent an additional $3,079, of which $2,270 was for energy efficiency measures and $809 was for on-site generation. Numerous financial tools were used to keep net costs at a minimum, including additional low income housing tax credits, federal solar business investment tax credits, solar and energy efficiency rebates, and conventional debt. While complex, none of these tools are either out-of-reach for typical affordable housing projects in California, nor are they esoteric in the industry. A replicable business model does exist for zero energy affordable housing.

There are barriers to implementing this business model throughout California’s affordable housing industry. Technically, it is difficult to build zero energy multifamily buildings at a height greater than two stories tall if air conditioned, and taller than three stories if naturally cooled. As a result of the two zero energy projects, regulatory issues surrounding net metering requirements of multifamily buildings and the utility allowance rate structure of affordable

housing were publicized and then changed in ways that should make it easier to develop these projects in the future. It is too early to assess whether these regulatory changes are having their intended impact.

Keywords: Zero energy, energy efficiency, affordable housing, multifamily housing, business model for zero energy, utility allowance, virtual net metering

Executive Summary

Introduction

This report documents the activities of the Global Green USA team in developing, designing, constructing, and monitoring the performance of two net zero electricity affordable housing developments. The report also summarizes lessons learned and describes how those lessons have been communicated to various affordable housing stakeholders, the solar photovoltaic community, and a variety of California state agencies.

In 2008, state energy policymakers set a bold target in its long-range energy efficiency plan to achieve zero net energy consumption for all newly constructed residential buildings by 2020. Achieving zero net electricity, as attempted by the affordable housing complexes in this research project, is a major component of reaching the more aggressive zero energy goal, which encompasses natural gas as well as electricity.

Within the residential building sector, different building types, market niches, and investment structures generate a diversity of issues in the process of pursuing zero energy goals, and affordable housing is no exception. The importance of the multi-unit building type and low-income housing market should not be underestimated. In 2009, 27% of all new housing starts in California were multifamily buildings. In the urbanized coastal areas of Southern California and the San Francisco Bay Area, multifamily buildings account for a least half of the new residential construction market. Statewide, the affordable housing development community produces approximately 10,000 units per year, most of which are in multifamily developments.

The financial model for affordable housing is very different from market-rate developments. Affordable housing utilizes a combination of federal tax credits, state bond-backed loans, local redevelopment funds, and premium priced long-term debt from either non-profit or commercial banks. These investments are understood to be long-term, as the goal is for the developers to provide affordable housing for many years. Thus the expectations about the timing and size of return on investment, are very different from the market-rate multifamily sector. Instead of short-term return on investors' equity, in terms of energy performance affordable housing is focused on the long-term economic benefits of utility bill reduction for both the operators of the developments and the low-income tenants.

In 2005 the PIER Program awarded a contract to a team led by Global Green to develop two Zero Energy New Homes (ZENH), in cooperation with two non-profit affordable housing developers. Guided by the PIER solicitation, the ZEHN affordable housing projects attempted to meet four basic criteria: 1) deliver a 70% annual electricity cost reduction compared to a typical new affordable housing project; 2) designed to be 25% better than the 2005 California Title 24 energy efficiency standards; 3) have a maximum peak demand of no greater than 1 kW; and 4) require no more than $5000 in additional first costs, after rebates and incentives, for energy efficiency upgrades and on-site electricity generation.

While these criteria were used as goals for the design, financing, and implementation of the two net zero affordable housing projects, the larger objective of the research effort, consistent with the original solicitation, was to identify viable and sustainable business models for net zero affordable housing in the state of California.

Project Approach

Key to the research effort was the design and construction of two affordable housing developments aiming for the ZENH goals. The first project, Solara, is a 56-unit affordable housing complex in the City of Poway in inland north San Diego County. It opened in the spring of 2007. It is located in California's Climate Zone 10, characterized by hot/dry summers and ample year-round sunshine. The units, a mix of one-, two-, and three-bedroom garden-style apartments, are spread over six separate two-story residential buildings. It serves families making between 30% and 60% of Area Median Income and was developed by non-profit Community HousingWorks. In 2008, Solara was chosen as one of the 10 best projects of the year by the Urban Land Institute.

The second project, Los Vecinos, is a 42-unit affordable housing complex in the City of Chula Vista in coastal South San Diego County. It opened in the spring of 2009. It is located in California's Climate Zone 7, characterized by mild summers and ample year-round sunshine. The units, a mix of one-, two-, and three-bedroom apartments, are located in one three-story residential building. It serves families making between 30% and 60% of Area Median Income and was developed by non-profit Wakeland Housing and Development. In 2009 it received LEED Platinum certification and was named Multifamily Project of the Year by the United States Green Building Council.

Both projects were monitored for performance. PV electricity production, gross electricity consumption, electricity cost, and peak electricity demand, and natural gas consumption and cost were all measured and analyzed. To provide a baseline, the same items were monitored at two nearby affordable housing projects built and owned by the same developers.

Additional first costs to reach net zero electricity – or close to it – were significantly less than the $5,000 goal at each of the two projects. Solara spent an additional $2,102, of which $656 was for energy efficiency measures and $1446 was for on-site generation. Los Vecinos spent an additional $3,079, of which $2,270 was for energy efficiency measures and $809 was for on-site generation. Numerous financial tools were used to keep net costs at a minimum, including additional low income housing tax credits, federal solar business investment tax credits, solar and energy efficiency rebates, and conventional debt.

Project Outcomes

Solara exceeded 2005 Title 24 by approximately 15% and 2001 Title 24 by 40%, reduced electric utility costs by 62%, and had a peak summer demand of well below 1 kW throughout the year. Solara was a net exporter of electricity at the time of the local utility peak for nine out of twelve months of the year, including the annual system peak in the summer. Los Vecinos was 43% better than 2005 Title 24, reduced electric utility costs by 62% and had a summer peak demand of well below 1 kW throughout the year. Los Vecinos is a net exporter of electricity during the four hottest months of the year.

The ability of affordable housing developers to implement the ZENH business model does not depend on whether these specific operational targets have been met. Rather, the most important operational consideration is whether the modeled financial scenarios and expected performance goals were actually delivered. Actual performance versus expected performance is the criterion by which other affordable housing developers and their financial partners will judge the success or failure of the project as a whole.

At Solara, actual results for gross electricity consumption, electricity bill reduction, and PV production were all within 9% or less of expected results. Net electricity consumption was 29% less than expected. PV production for each unit was relatively consistent, but the gross electricity consumption of each unit varied widely. Annual gross consumption per bedroom ranged anywhere from 668.7 kWh to 4557.4 kWh, which represents almost an order of magnitude variation. As at Solara, PV production for each unit at Los Vecinos was relatively consistent, but the consumption of each unit varied widely. Individual annual gross consumption per bedroom ranged anywhere from 328 kWh to 2397 kWh, again almost an order of magnitude variation.

At Los Vecinos, gross electricity consumption was 19% less than expected and PV production was 13% greater than expected, leading to utility bill reductions that were in line or greater than expected. Approximately one-third of the units were net electricity exporters, but still paid minimum charge of $5.17 per month; net zero electricity did not equate to electricity bills of zero.

These results suggest that while the projects delivered on the performance and financial benefits that were expected, the ability to achieve zero energy use on a per unit basis depends largely on individual occupant behavior. These three themes of project performance, financial benefits and occupant behavior guided the overall message of the more than two dozen presentations about zero energy affordable housing given over to the course of the research program to groups of affordable housing developers, designers and funders, as well as the solar industry.

One tangible outcome of these outreach activities was two important changes to regulatory barriers that stood in the way of optimal design and financial outcomes at Solara and Los Vecinos. On the design side, Virtual Net Metering (VNM) tariffs were approved by the California Public Utilities Commission in mid 2009. VNM tariffs lower equipment costs by approximately $1,000 per unit and greatly simplify solar system design by allowing affordable housing projects to install one master meter and inverter to measure the amount of electricity generated by the photovoltaic system. Individual apartments are still individually metered for consumption, but their monthly utility bills automatically are credited with a percentage of the electricity generated by the photovoltaic system.

The regulatory change with the largest potential financial impact is the development by the Energy Commission of the California Utility Allowance Calculator (CUAC), which uses Title 24 modeling and other inputs to generate a project-specific utility allowance pegged to actual project characteristics. Use of the CUAC allows both tenants and owners to share in the financial benefits of ZENH strategy implementation and removes one of the key financial barriers previously faced by project developers.

Conclusions

Three main conclusions regarding financing, design, analysis, and applicability of zero energy affordable housing in California can be drawn from the Global Green-led research program.

First, zero energy affordable housing projects are financially viable. Through the combination of affordable housing tax credits, federal solar investment tax credits, state rebates for energy efficiency and solar installations, and additional debt leveraged from energy cost savings, developers can fully cover the first cost of constructing a net zero electricity building. While complex, none of these tools are either out-of-reach for typical affordable housing projects in California, nor are they esoteric in the industry. Thus a replicable business model does exist for zero energy affordable housing.

Second, energy cost modeling can be accurate enough to underwrite the additional debt necessary to finance zero energy affordable housing projects. Being able to estimate future utility costs with a reasonable degree of accuracy is critical to the zero energy affordable housing business model. By using a combination of state approved software, daily charge rates from the utility, information on occupant behavior, and careful analysis of expected plug loads, it is possible to predict the energy savings with a sufficient degree of accuracy to support utility allowance and overall operating cost adjustments

The third major conclusion is that taller buildings pose a challenge for regulators as they seek to turn zero energy into a code mandate over the next decade. Based on the outcomes of this research project, there appears to be a height limit of three stories on residential buildings seeking to achieve net zero electricity goals using current technology. Advances in photovoltaic efficiency and lighting electricity consumption, along with more stringent appliance standards to lower plug load, will all be necessary if buildings over three stories are to meet future zero energy requirements. These advances are also necessary if California communities are to both build zero energy buildings and still be able to achieve the residential unit density necessary to construct the walkable transit-oriented communities that are crucial to reducing transportation-based greenhouse gas emissions statewide.

Recommendations

A number of key recommendations can be drawn from the conclusions.

1. More precision is needed with respect to the definition of "zero energy." That definition needs to take into account the multiple variations in building type, climate zone, system selection, and rebate and incentive levels.
2. Plug load and lighting consumption need to be reduced – and therefore more stringently regulated – if zero energy multifamily buildings are to be constructed on a wider scale.
3. The turmoil in the low income housing tax credit market, and the resulting slow uptake of zero energy projects in the affordable housing industry over the past two years should not be used as a justification to dismantle the overall structure of incentives and rebates that support the zero energy affordable housing business model.

Benefits to California

The following are the key benefits to the state generated by this project:

- The technical and financial feasibility of zero energy affordable housing developments has been demonstrated.
- A practical real world reference point for both state policymakers and staff in the housing, energy, and building codes agencies has been established.
- Key changes to regulations governing the housing finance, energy service, energy code, and building code elements of zero energy affordable housing projects were informed by the research program.

All tables and figures were provided by the author.

1.0 Introduction

This report documents the activities of the Global Green USA team in developing, designing, constructing, and monitoring the performance of two net zero electricity affordable housing developments. The report also summarizes lessons learned and describes how those lessons have been communicated to various affordable housing stakeholders, the solar photovoltaic community, and a variety of California state agencies.

Since the adoption of the Title 24 Building Energy Efficiency Standards in 1978, California has made the energy efficiency of buildings an ongoing priority. As building design and technology improved over the ensuing years, some state policy makers began to discuss the feasibility of buildings achieving “net zero” balance between energy used and energy generated on-site. In 2004, to explore the technical, financial, and regulatory feasibility of this goal, the California Energy Commission’s Public Interest Energy Research (PIER) Program released a solicitation for Zero Energy New Homes (ZENH) research. Subsequent to the awarding of contracts under this solicitation, the California legislature passed Assembly Bill 32 (AB 32) to reduce greenhouse gas emissions created by the signing of AB 32 into law in 2006 and state energy policymakers in 2008 set a bold target for energy consumption reductions from new buildings. The stated goal in State’s long-range energy plan is to achieve zero net energy consumption for all newly constructed residential buildings by 2020 and for all newly constructed non-residential buildings by 2030. Achieving net zero electricity, as attempted by the affordable housing complexes developed as part of this research project, is a major component of reaching the more aggressive zero net energy goal, which encompasses natural gas as well as electricity.

Global Green USA, a California-based non-profit environmental organization, worked with the Energy Commission and its consultants in 2004 to ensure that the solicitation covered multifamily building types and the affordable housing development sector. Within the residential building sector, different building types, market niches, and investment structures generate a diversity of issues in the process of pursuing net zero energy goals, and affordable housing is no exception. The importance of the multi-unit building type and low-income housing market should not be underestimated. In 2009, 27% of all new housing starts in California were multifamily buildings. In the urbanized coastal areas of Southern California and the San Francisco Bay Area, multifamily buildings account for a least half of the new residential construction market. Statewide, the affordable housing development community produces approximately 10,000 units per year, most of which are in multifamily developments.

Multifamily buildings have the inherent energy efficiency and greenhouse emission benefits of shared walls and smaller living spaces and levels of dwelling unit density that support public transit. Affordable multi-family developments provide further societal benefits by creating safe and decent housing for low-income individuals and families. Bringing high-level energy efficiency and on-site generation to these development enables the energy strategies to leverage the other benefits. Furthermore the financial model for affordable housing is very different from market-rate developments. Affordable housing utilizes a combination of federal tax credits, state bond-backed loans, local redevelopment funds, and premium priced long-term debt from either non-profit or commercial banks. These investments are understood to be long-term, as the goal is for the developers to provide affordable housing for many years. Thus the expectations about the timing and amount of the return on investment, are very different from the market-rate multifamily sector. Instead of short-term return on investors’ equity, affordable housing is focused on the long-term economic benefits of utility bill reduction for both the operators of the developments and the low-income tenants residing in zero energy affordable housing.

In response to the statements from Global Green and others, multifamily developments and affordable projects were included in the 2004 Zero Energy New Homes (ZENH) solicitation. The focus of the solicitation was to identify and refine sustainable business models for ZEHN developments. In 2005 the PIER Program awarded a contract to a team led by Global Green to develop two ZENH affordable housing projects, in cooperation with two non-profit affordable housing developers. Both projects are located in San Diego County. The first project, Solara, located in Poway, opened in the spring of 2007. The second project, Los Vecinos, located in Chula Vista, opened in summer of 2009.

Guided by the PIER solicitation, the ZEHN affordable housing projects attempted to meet four basic criteria:

- deliver a 70% annual electricity cost reduction compared to a typical new affordable housing project;
- designed to be 25% better than the 2005 California Title 24 energy efficiency standards;
- have a maximum peak demand of no greater than 1 kW;
- require no more than $5000 in additional first costs, after rebates and incentives, for energy efficiency upgrades and on-site electricity generation.

While these criteria were used as goals for the design, financing, and implementation of the two net zero affordable housing projects described in this report, the larger objective of the research effort, consistent with the original solicitation, was to identify viable and sustainable business models for net zero affordable housing in the state of California.

2.0 Project Approach

2.1. Program Overview

2.1.1. ZENH Definition and Criteria

Several definitions of what constitutes a zero energy home have proliferated over time. In the 1990s the United States' Department of Energy's Building America program defined a Zero Energy Home as one that produced 70% of its annual energy use on-site. Over time Building America's own definition has changed to emphasize energy efficiency first and raise the bar to 100% of annual consumption. At present, a standard working definition of a zero energy home is one with "greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies." This definition, which does not imply either carbon neutrality or being "off-the-grid," has become a standard working definition, notwithstanding a lack of precision with regard to technical issues of site versus source energy or whether excess on-site production of one type of renewable energy (e.g., electricity from renewables) could offset consumption of non-renewable energy (e.g., natural gas).

Under the California Energy Commission's 2004 PIER Zero Energy New Homes (ZENH) solicitation, what exactly constituted a zero energy home was never explicitly defined, nor was it a suggested outcome of the research. Over the course of the design of the solicitation in 2003 and 2004, a de facto definition emerged:

- 70% annual electricity cost reduction compared to a home built to code.
- 25% better than California Title 24 energy efficiency standards (2005).
- 1 kW maximum peak demand.
- $5000 maximum additional first costs, after rebates and incentives, for energy efficiency upgrades and on-site electricity generation.

2.1.2. ZENH Business Model for Affordable Housing

Beyond the technical and financial criteria called for by the PIER ZENH program goals, the research team was interested primarily in testing and refining a business model for zero energy new homes that would be specifically applicable to the affordable housing development community. The affordable housing community is important to include in any discussion of zero net energy buildings because its members develop approximately 10,000 dwelling units per year in California. Because the financing sources for affordable housing are different from those used by market rate developers, the number of affordable units built in California varies very little year-to-year and is not subject to the boom and bust cycles of the market-rate new home building industry. Affordable housing developers also typically build multifamily buildings, which are becoming an increasing portion of the state's residential building stock.[1] In addition, affordable housing builders, given their social mission and captive market, have typically shown a greater appetite for financial and energy efficiency innovation than their market rate counterparts. Finally, this market's reliance on government subsidies to build their developments provides an opportunity to leverage government spending to deliver the additional public benefits associated with zero energy homes.

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[1] In 2009 in California, 27% of all new housing starts were multifamily buildings and in key urbanized coastal areas, multifamily buildings account for half or more of the new residential construction market. See monthly and annual production numbers by state and Metropolitan Statistical Area available at: www.nahb.org/reference_list.aspx?sectionID=130

The affordable housing financial model and ownership structure are very different than those used by market rate builders, necessitating a different business model to facilitate the development of zero energy homes. This business model must take into account several factors that characterize the ownership structure, rent-setting policy, and government programs that govern the vast majority of affordable housing in California. These factors include the following:

- Long-term ownership of each property by a group of investors with an expected tax liability.
- Monthly rents that are guaranteed to be affordable for low-income individuals and families for 55 years or more, thus limiting the ability to increase cash flow over time.
- Monthly rents that take utility costs into account when determining the definition of an affordable rent.
- A fixed construction budget that, while not generous, must be spent in its entirety, thus eliminating the incentive to cuts costs in order to increase profit.
- An array of incentives and rebates that are available for highly energy efficient affordable housing projects that incorporate renewable energy generation – including additional low income housing tax credits, solar business investment tax credits, and enhanced utility-administered solar and energy efficient rebate levels.

Together these characteristics make for projects that are relatively cash-rich during construction and very cash-poor during operations. This overall financial condition makes them particularly suited to engage in the development of low or zero energy housing. Section 2.3 describes in detail the financial characteristics of the business model developed by this ZENH research program.

2.1.3. Partner Developers

The developer partners for the ZENH research program were two San Diego based non-profit developers: Community HousingWorks, developer of Solara, and Wakeland Housing and Development, developer of Los Vecinos.

Community HousingWorks (CHW) is a 20-year old organization that has developed over 1300 units of affordable housing in urban, suburban, and rural locations in San Diego County. While the organization's developments have won awards from the California League of Cities, the California Redevelopment Association, and Pacific Coast Builders, prior to the construction of Solara, it had limited experience with green building in general and aggressive energy efficiency strategies in particular. CHW had never installed a solar photovoltaic (PV) system before. This lack of experience extended to many of Solara's key design team members, including the architect, general contractor, mechanical engineer, and electrical engineer.

Wakeland Housing and Development (Wakeland) is a 15-year old organization that has a portfolio of over 6,000 units of affordable housing throughout California. Wakeland's new developments are concentrated in urban and suburban San Diego County. Prior to Los Vecinos, its projects had won awards from the Urban Land Institute, the California Redevelopment Association, and the San Diego Housing Federation. Prior to construction of Los Vecinos, Wakeland had already benefited from contact with the Gas Technology Center, which conducted initial energy efficiency studies and modeling for Los Vecinos. In addition, during the design phase of Los Vecinos, Wakeland was simultaneously bidding out its first PV installation, a system to power the common areas of a new high-rise residential project in downtown San Diego. Being the second project in the ZENH program and using some of the same design team members as Solara, including the same architect, made the Los Vecinos design team somewhat more aware of advanced energy efficiency techniques, green building measures, and renewable energy installations.

Both developer partners had similar interests in participating in the ZENH program and in building very low energy buildings. The prospect of finding a financial solution that would leverage a first-cost investment and available incentives into long-term financial savings was attractive. Both developers were operating in cities that either had a track record for supporting energy efficiency (Los Vecinos in Chula Vista) or wanted to experiment in this area (Solara in Poway) and were willing to support the projects both financially and administratively. Both developers are astute politically and seek to position themselves ahead of any impending code changes. Finally, for affordable housing which often faces difficulty in securing approval from neighbors and local governments, pursing innovative and cutting edge environmental building practices into these developments can help build community support for current and future projects. For all these reasons, both developers were already seeking to implement very low energy building strategies on Solara and Los Vecinos when they decided to join the ZENH program team.

2.1.4. Overview of Solara and Los Vecinos

Key to the research effort was the design and construction of two affordable housing developments aiming for the ZENH goals.

Solara

Solara is a 56-unit affordable housing complex in the City of Poway in inland north San Diego County (see Figure 1 for an aerial view of the finished complex). It opened in the spring of 2007. It is located in California's Climate Zone 10, characterized by hot/dry summers and ample year-round sunshine. The units, a mix of one-, two-, and three-bedroom garden-style apartments, are spread over six separate two-story residential buildings. A seventh one-story building contains the management office, community space, a computer center, and common laundry facilities. Residents have access to surface parking, some of which is covered by carports. Located on a 2.5 acre site, the project can best be characterized as suburban infill; it is close to shopping, parks, neighborhood services and public transportation, all within a suburban setting. It serves families making between 30% and 60% of Area Median Income. In 2008, Solara was chosen as one of the 10 best projects of the year by the Urban Land Institute.

After construction and a start-up phase, Global Green's project team monitored the performance of 28 of the 56 units at Solara for 12 months. PV electricity production, gross electricity consumption, electricity cost, and peak electricity demand, and natural gas consumption and cost were all measured and analyzed. In order to provide a baseline that Solara could be compared to, the same items were monitored during the same period in four units at Hillside, a nearby affordable housing complex built and owned by the same developer but with no photovoltaics and a limited amount of energy efficiency upgrades.

Figure 1: Aerial view of Solara

Los Vecinos

Los Vecinos is a 42-unit affordable housing complex in the City of Chula Vista in coastal South San Diego County (see Figure 2 for an aerial view). It opened in the spring of 2009. It is located in California's Climate Zone 7, characterized by mild summers and ample year-round sunshine. The units, a mix of one-, two-, and three-bedroom apartments, are located in one three-story residential building. A portion of the ground floor of the building contains the management office, community space, a computer center, and common laundry facilities. Parking is available in a surface lot (part of which is covered by carports) and spaces under the building on the ground floor. Located on a 1.35 acre site, the project is an example of urban infill and is denser than its immediate surroundings. It is close to shopping, neighborhood services, and public transportation, including a light rail stop. It serves families making between 30% and 60% of Area Median Income. In 2009 it received LEED Platinum certification and was named Multifamily Project of the Year by the United States Green Building Council.

After construction and a start-up phase, the project team monitored the performance of 22 of the 42 units for six month. PV electricity production, gross electricity consumption, electricity cost, and peak electricity demand, and natural gas consumption and cost were all measured and analyzed. In order to provide a baseline that Los Vecinos could be compared to, the same items were monitored during the same period in ten units at Beyer Apartments, a nearby affordable housing complex built and owned by the same developer but with no photovoltaics and a limited amount of energy efficiency upgrades.

Figure 2: Aerial View of Los Vecinos

2.2. ZEHN Project Strategies

2.2.1. Energy Efficiency and Solar Production Analysis Methodology

Each of the two projects used a similar methodology to arrive at its particular combination of energy efficiency measures and photovoltaic system sizing, which are the two key components in designing a ZENH building.

First, the project team analyzed site conditions and optimized building orientation for maximum passive cooling and solar production within the constraints of the program and site.

Second, the team explored schematic design options in terms of both building envelope measures and HVAC/domestic hot water options and created models in EnergyPro, one of the standard energy code compliance software programs used in California. Outputs from EnergyPro give an approximation of annual electricity and natural gas usage for loads regulated under Title 24 energy code, including space cooling, space heating, domestic hot water, and fan energy use. These outputs were then added to expected electricity usage from non-regulated loads and loads controlled by prescriptive code requirements, including lighting, appliances and plug loads to arrive at an electricity and natural gas estimate for each scheme.[2] It is important

[2] The final electricity estimate was also adjusted to account for items not considered in EnergyPro low-rise residential load calculations, such as plug and lighting loads that generate heat.

to note that non-regulated and prescriptive loads can be difficult and time-consuming to estimate and can account for 50% or more of a building's electricity usage.

Third, the team explored roof designs to estimate how many PV panels could fit and in what configuration. Variables in roof design and their effect on overall electricity production include roof orientation, roof slope, potential shading effects of parapets and trees, location of mechanical equipments and vents, and the technical need to batch PV panels into arrays and strings based on inverter size. Regulations regarding panel visibility from the street or clearances that may be imposed by local planning or fire officials can also affect expected PV production. In addition, the team analyzed the site for the potential to add PV panels in other places, particularly carports. Team members modeled each of these potential solar panel configurations using the online estimating program PV Watts to determine annual electricity output in kilowatt-hours (kWh) from a variety of configurations.[3]

Fourth, the kWh usage of various energy efficiency options was correlated to the potential kWh production of the site, given the numerous constraints on PV system design noted above. The team then analyzed the cost and construction feasibility of each option to arrive at a suitable combination of energy efficiency design and PV system size and configuration.

Although the analysis that was used to ultimately decide the overall energy design of the projects was supported by quantitative and technical data on cost and energy performance, what ultimately determined the final decision on configuration was financial, combined with qualitative issues regarding project design and delivery. At Los Vecinos, the project team had already elected to pursue the most electricity efficient option as possible (see Section 2.2.2), so the main issue was figuring out where on the project site to fit enough PV panels . At Solara, the particular mix of incentives at the time of design favored PV over energy efficiency, so the project put as many PV panels as it could and then adjusted expenditures on energy efficiency accordingly to meet the ZENH electricity cost reduction goal. This latter method contradicts the typical zero energy home design approach; the incentive structure that dictated this approach is described more fully in Section 2.3.

2.2.2. Project Energy Characteristics

Every one of the Solara's six residential buildings is oriented on an east-west axis. This orientation supported the project's energy goals but was a change from the original project design that had many of the buildings oriented north-south in order to maximize the number of apartments with views of the greenway adjacent to the site. The building massing of traditional garden-style apartments placed back-to-back was primarily dictated by the need to maintain some continuity with the surrounding residential architecture. This massing provides through ventilation opportunities only in the corner units, which comprise about 40% of the total units on-site. In addition to flat roofs, the project also incorporated false shed roofs at various angles to further distinguish the project from the adjacent less visually attractive apartment complexes.

Los Vecinos' building orientation is longer on the east-west axis, but only slightly, given the tight site and the architectural desire to have the building entrance directly front the street. However, building orientation in a mild climate provides fewer benefits as long as the building itself has a flat roof upon which solar panels can be oriented on racks in any direction. More important at the Los Vecinos site is building form and shape, given that the project is not mechanically cooled, relying instead on open windows and ceiling fans for ventilation. In

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[3] Although the Energy Commission's own New Solar Homes PV calculator is more exact than PV Watts, it was not available until after the design phase of each project was completed.

this respect, the project succeeds by eliminating conditioned double-loaded corridors (enclosed corridors with unit entries on both sides). However, a lack of windows or other openings on the unconditioned corridor side reduces the opportunities for cross-ventilation.

Given these building orientation and massing characteristics, Table 1 lists the energy efficiency and solar photovoltaic design features of each project, compared to 2005 Title 24 energy code requirements.

Table 1: Comparison of Solara and Los Vecinos Energy Features with California Energy Code

Features	Title-24 (2005) Requirements	Solara	Los Vecinos
Attic Insulation	R-30	R-30	R-49
Wall Insulation	R-13	R-13	R-19
Radiant Barrier	No	Yes	No
Insulation Installation Quality Inspection	No	Unofficial	Yes
Low Air Infiltration Test	No	Unofficial	No
Glazing (U-factor and SHGC)	0.41 U-factor 0.41 SHGC	0.35 U-factor 0.35 SHGC Low-E	0.39 U-factor 0.36 SHGC Low-E
Fixed Exterior Shading of Windows	No	Yes	No
Water Heating	Central gas-fired system with 80 % recovery efficiency plus standby losses from storage tank OR individual tank-type water heaters	Central gas-fired system of multiple tankless hot water heaters with 82% recovery efficiency	Individual gas-fired tankless water heaters with 83% recovery efficiency
Aquastat recirculation pump	No	Yes	NA
Space Heating	80% AFUE gas-fired furnace	Central hydronic fan coil ducted system with 82% recovery efficiency gas-fired tankless hot water heater and 30 gallon storage tank – the same tankless water heaters that are used for domestic hot water heating	Individual hydronic fan coil ducted system with 83% recovery efficiency gas-fired tankless water heaters – the same tankless water heaters that are used for domestic hot water heating
Air Conditioning efficiency	13.0 SEER	13 SEER with TXV (1 and 2 bedroom units) 14 SEER with TXV (3 bedroom units)	NA (Ceiling fans only)
Duct Insulation / Location	R-4.2 for unconditioned spaces	1st floor units have ducts located entirely in conditioned space; R-4.2 in unconditioned spaces	R-4.2

Features	Title-24 (2005) Requirements	Solara	Los Vecinos
Tight Ducts	Yes (not third party tested)	Not third party tested	Yes – third party tested
Adequate Airflow Inspection	No	Yes	NA
Lighting	Mix of permanently installed pin-type fluorescent fixtures in kitchens and baths with incandescent fixtures in other spaces	All rooms have permanently installed pin-type fluorescent fixtures	All rooms have permanently installed pin-type fluorescent fixtures
Appliances	NA	Energy Star Refrigerator Energy Star Dishwasher Energy Star Commercial Washers and Gas Dryers located in Community Building	Energy Star Refrigerator Energy Star Dishwasher Energy Star Commercial Washers and Gas Dryers located in Common Area
Cooking	NA	Electric Range and Oven	Gas Range and Oven
PV System Characteristics	NA	141 kW DC (121 kW for units, 20 kW for common areas)	94 kW DC (74 kW for units, 20 kW for common areas)
PV Unit System Sizes	NA	2.0 – 2.4 kW/3 bedroom 1.7 – 2.4 kW/2 bedroom 1.7 – 2.4 kW/1 bedroom	1.4 – 1.6 kW/3 bedroom 1.4 kW/2 bedroom 1.2 kW/1 bedroom
Title-24 (2005) Performance	Baseline	12%-15% better depending on building	43% better

Two anomalies exist with regards to the Title 24 results presented in Table 1. First, at Solara, the natural gas savings from the unusual and innovative centralized tankless-fed hydronic heating system are undercounted by the EnergyPro software. Second, at Los Vecinos, 92% of the regulated load savings reported by EnergyPro are derived from natural gas savings measures, principally domestic hot water.

From an electricity usage standpoint, the two projects are configured almost exactly the same, with the exception of the presence of air conditioning and electric cooking at Solara and natural cooling and gas cooking at Los Vecinos. These differences largely explain the smaller photovoltaic sizing at Los Vecinos compared to Solara.

2.3. Financing the ZENH Strategies

Solara and Los Vecinos were both able to design and construct ZENH buildings using trusted energy efficiency techniques and off-the-shelf technology. More groundbreaking was the financial package that the projects put together in order to pay for the ZENH features. This package combined several sources of financing to do two things. First, the financing package reduced the upfront, or net, cost of the energy efficiency measures and on-site photovoltaics. Second, the financing package used ongoing operational savings from the ZENH measures to provide additional cash flow to the projects, thus allowing the projects to borrow the additional money necessary to pay for the first cost gap that remained.

The strategy used by the developers to capture the operational savings from the ZENH measures and turn it into additional debt for the projects was different at Solara and Los Vecinos. At Solara, the developer included all utility payments in the rent and did not give the tenants a utility allowance. This allowed the developer to capture all the potential financial savings while providing tenants with a stable and secure monthly utility charge. However, this did expose to the developer to significant down-side risk should tenants end up consuming more energy than expected and may have played a role in the wide variation of gross utility usage among different units at Solara.

At Los Vecinos, the developer benefitted from a special self-generation utility allowance schedule offered by the Housing Authority of the City of Chula Vista. This schedule decreased utility allowances for tenants by 75% based on the expected performance of the project, while keeping the tenants responsible for paying the utility bills. The net effect of this approach was to allow the developer to increase rents but maintained the overall rent plus utility burden for tenants below the required 30% of total family income. It also gave tenants feedback on their energy usage and a financial incentive to save energy, while at the same time protected the developer from tenants who used excessive amounts of energy. With the release of the California Utility Allowance Calculator (see Section 3.2.2), the approach taken by Los Vecinos is the method other affordable housing developers are following when developing very low energy buildings in the state.

Table 2 through Table 7 break down the gross costs, sources of financing, and net costs of the energy efficiency measures and PV systems at Solara and Los Vecinos. Since most affordable housing projects in the state of California already exceed the state's energy code by 10% to 15% as a condition of funding, the gross cost of energy efficiency measures described in the tables are for those measures that specifically helped the projects attempt to meet their 70% electricity cost reduction goals. Put another way, these gross costs are for those measures that reduced electricity consumption above and beyond what a typical affordable housing project would incorporate. At Solara the net cost of energy efficiency and PV was $2,102 per housing unit. At Los Vecinos the net cost of energy efficiency and PV was $3,079 per unit. Thus each project met the ZENH goal of these measures adding no more than $5,000 in net costs per unit.

Table 2: Solara Energy Efficiency Costs and Sources of Funding

Costs		Sources	
Energy Efficiency Upgrades Necessary to Meet 70% Electricity Cost Reduction Goal	$48,712	Utility Rebates	$12,000
		Gap Financed with Additional Low Income Housing Tax Credits[4]	$36,712
Total Costs	**$48,712**	**Total Sources**	**$48,712**

Table 3: Solara PV Costs and Sources of Funding

PV Costs		PV Sources	
Base Cost	$967,500	Additional Low income	$405,000

[4] A portion of the extra funds the project received by claiming the 4% threshold basis limit increase that the California Tax Credit Allocation Committee offers for sustainable building measures.

		Housing Tax Credits[5]	
General Contractor Markup	$135,500	Federal Solar Tax Credits	$208,000
		State Solar Rebate (Emerging Renewables Program)	$409,000[6]
		Gap financed with conventional debt	$81,000
Total Costs	**$1,103,000**	**Total Sources**	**$1,103,000**

Table 4: Solara Net Cost of Energy Efficiency Features and PV Systems per Apartment Unit

Net Energy Efficiency Costs per Housing Unit	Net PV Costs per Housing Unit	Total Energy Efficiency and Photovoltaics per Housing Unit
$36,712 ÷ 56 units = $656	$81,000 ÷ 56 units = $1446	$2102

Table 5: Los Vecinos Energy Efficiency Costs and Sources of Funding

Costs		Sources	
Energy Efficiency Upgrades Necessary to Meet 70% Electricity Cost Reduction Goal	$102,050	Utility Rebates	$6,700
		Gap Financed with Additional Low Income Housing Tax Credits[7]	$95,350
Total Costs	**$102,050**	**Total Sources**	**$102,050**

Table 6: Los Vecinos PV Costs and Sources of Funding

PV Costs		PV Sources	
Base Cost	$848,523[8]	Additional Low income Housing Tax Credits[9]	$344,953
3rd Party Testing	$2,925	Federal Solar Tax Credits	$161,137
		State Solar Rebate	$311,400[10]

[5] Total amount of the extra funds the project received by claiming the 5% threshold basis limit increase that the California Tax Credit Allocation Committee offers for onsite generation.

[6] Approximately $2.90 per watt.

[7] A portion of the extra funds the project received by claiming the 4% threshold basis limit increase that the California Tax Credit Allocation Committee offers for sustainable building measures.

[8] Includes General Contractor markup.

[9] Total amount of the extra funds the project received by claiming the 5% threshold basis limit increase that the California Tax Credit Allocation Committee offers for on-site generation.

		(New Solar Homes Partnership)	
		Gap financed with conventional debt	$33,958
Total Costs	**$851,448**	**Total Sources**	**$851,448**

Table 7: Los Vecinos Net Cost of Energy Efficiency Features and PV Systems per Apartment Unit

Net Energy Efficiency Costs per Housing Unit	Net PV Costs per Housing Unit	Total Energy Efficiency and Photovoltaics per Housing Unit
$95,350 ÷ 42 units = $2,270	$33,958 ÷ 42 units = $809	$3,079

2.3.3 Incentive Structure Bias toward PV (Solara)

Given the subsidies noted in the previous section and the fact that the project incurred only $656 per unit in additional energy efficiency costs, the Solara project team did consider installing additional premium energy efficiency measures. However, a closer look now at the costs and sources of funding demonstrates that at the time of that project's design and construction, the incentives for installing additional PV were higher than for further energy efficiency measures. Table 8 outlines the premium energy efficiency measures considered for the Solara project, and Tables 9 and 10 show comparisons to PV.

Table 8: Premium Energy Efficiency Measures Considered

Premium Energy Efficiency Measures	% Savings above Title-24 2005 (per measure)
AC refrigerant charge inspection	3.0%
Insulation quality Inspection	2.7%
Air barriers	0.7%
15.5 SEER / 12 EER Air Conditioners	5.3%
R-19 wall insulation (2x6 framing)	2.9%
R-38 ceiling insulation	1.1%
R-8 duct insulation (for ducts in unconditioned spaces)	0.3%
Cool roof	0.6%
Condensing water heaters for Domestic Hot Water and Space Heating Hot Water	5.5%
All Measures	20.2%

The data in Table 8 indicate that if this entire premium energy efficiency package were to have been implemented, the project would have been approximately 31% better than Title 24 (2005).

Three of the proposed premium energy efficiency measures were not incorporated into the building design for technical and/or performance reasons. The "fatal-flaw" of each of these measures is explained below.

- R-19 Wall Insulation: When the project entered the ZENH program, the site plan, the dimensions of the building footprint, the building height, and the unit size had already been determined and, crucially,

[10] Approximately $3.50 per watt for apartment unit systems and $3.30 per watt for common area system.

approved by the Poway City Council as a part of the project's receipt of a Conditional Use Permit. Those dimensions had been set according to the architect's assumption of 2x4 inch framing, which allows for R-13 insulation. Moving to 2x6 framing, which allows for R-19 insulation, would have required either a) expansion to the exterior with resulting changes to the site plan and the building footprint dimensions, or b) contraction to the interior with resulting shrinkage of interior usable space. In order to move this project beyond the concept stage, the project developers had to overcome community opposition to building affordable housing in this location. The project developers were therefore unwilling to approach the City Council to request any modifications that would reopen the Conditional Use Permit for public comment. Thus, the option of R-19 wall insulation was discarded.

- Air Conditioning with 15.5 SEER: Because of the large impact of air conditioning on electricity consumption, high efficiency air conditioning units were initially specified for the project. The project developer recognized that the additional first cost of upgrading to 15.5 or 16 SEER air conditioners could be recouped in energy savings and would lower the size of the PV systems necessary to meet other ZENH goals. However, after much research, the project team could not locate an air conditioning condensing unit/fan coil package rated higher than 14 SEER that could also physically fit into the building. The major design limitation was that the area containing the ductwork could accommodate an 11" fan coil, while the fan coils necessary to reach 15.5 to 16 SEER rating were 20" high.[11] To accommodate these larger fan coils would have required a major building redesign that increased floor-to-floor height of 9" per story, or a total increase of 18" in building height. The developer indicated an unwillingness to ask for a modification of the Conditional Use Permit. Thus the option of higher efficiency air conditioning was discarded.
- Cool Roof: The project team also considered installing a heat-reflective cool roof. However, with this option there is a divergence between the energy model and the actual performance of the building. While the model predicted a 1% efficiency gain from the cool roof, the actual improved energy performance of the building would be negligible because almost the entire roof would be covered with solar photovoltaic panels. Given that, at the time of design and bidding of the project, cool roofs cost more than conventional roofs and that there would be little positive impact on energy performance, this option was dismissed as an unnecessary expenditure of resources.

The project team then analyzed the remaining premium energy efficiency measures for cost effectiveness. Table 9 and Table 10 show the results of this analysis. Two premium measures showed payback levels of ten years or less, two premium measures were more cost effective than installing additional PV, and no premium measures were more cost effective than the subsidized cost of installing additional PV.

Table 9: Payback of Premium Energy Efficiency Measures

Energy Efficiency Measure	Cost of Measure[12]	$ Energy Savings (Annual)	Payback (years)
AC refrigerant charge inspection	$4,000	$430	9.3

[11] Even if the correct fan coil could have been placed within the building, to get the specified SEER level would have required oversizing the condensing unit to 3 tons when unit sizes of 1.5 tons, 2 tons, and 2.5 tons were the correct sizes as determined by the Mechanical Engineer.

[12] Cost and savings data are for the entire project.

Insulation installation quality inspection	$4,000	$464	8.6
Air barrier (Tyvek)	$30,000 ($5,000 per building)	$148	202.7
R-38 ceiling insulation	$5,718	$87	65.7
R-8 duct insulation (for ducts in unconditioned spaces)	$1,400	$44	32.2
Condensing water heaters for Domestic Hot Water and Space Heating Hot Water	$90,000	$1,540	58.4

Table 10: Cost of Premium Energy Efficiency Measures Compared to Cost of Solar[13]

Measure	Cost of Measure	Avoided PV Cost (gross)	Avoided PV Cost (subsidized)	Difference (gross)	Difference (subsidized)
AC refrigerant charge inspection	$4,000	$15,749	$2,051	$11,749	($1,949)
Insulation quality Inspection	$4,000	$10,085	$1,314	$6,085	($2,686)
Air barriers (Tyvek)	$30,000	$1,111	$145	($28,889)	($29,855)
R-38 ceiling insulation	$5,718	$555	$72	($5,163)	($5,646)
R-8 duct insulation	$1,400	$1,355	$176	($45)	($1,224)
Condensing water heaters for DHW and Space Heating	$90,000	$0	$0	($90,000)	($90,000)

Note: In the last two columns, positive numbers indicate that the energy efficiency measure is more cost effective than additional PV. Negative numbers indicate that additional PV panels are more cost effective than energy efficiency.

13 In this climate zone and with PV pricing at the time of design and bidding, the gross cost of solar to produce 1 kWh was $4.76, while the subsidized cost of solar – after rebates and tax credits – to produce 1 kWh was $0.62.

3.0 Project Outcomes

3.1. Monitoring Results

3.1.1. Performance Results

Both Solara and Los Vecinos were modeled and compared to baseline projects (Hillside and Beyer respectively) to see if they reached the ZENH targets of 70% electricity cost reduction, 25% better than 2005 Title 24, and 1 kW maximum peak demand. With the exception of the Title 24 target for Solara, the projects essentially met those performance goals. Table 11 and Table 12 provide a summary of these results. The full monitoring reports, which provide a wealth of information regarding net and gross electricity and gas consumption, a discussion of how particular design strategies affected overall performance, impact of the projects on the electricity grid, and the monitoring methodology, are provided as Appendices A and B of this report

Table 11: Summary of Solara Performance with Respect to ZENH Program Goals

	ZENH Goal	Solara Performance	
		Modeled	Monitored
1. Title 24 Energy Performance Above Code	25%	12-15%[14]	NA[15]
2a. Electricity Cost Reduction (*Per Housing Unit*)	70%	85%	68%
2b. Electricity Cost Reduction (*Normalized per SF*)			62%
4. Per *Apartment* Summer Peak Demand (kW)	1 kW	NA[16]	-0.17 kW

Table 12: Summary of Los Vecinos Performance with Respect to ZENH Program Goals

	ZENH Goal	Los Vecinos Performance	
		Modeled	Monitored Performance
1. Title 24 Energy Performance Better than Code	25%	43.1%	NA
2a. Electricity Cost Reduction (*Per Apartment*)	70%	85%	70%
2b. Electricity Cost Reduction (*Normalized per SF*)			62%
3. Per Apartment Summer Peak Demand (kW)	1 kW	NA[17]	-0.30 kW

[14] Range depends on building/unit type and orientation

[15] Title 24 performance data cannot be directly compared with monitored data because Title 24 calculations do not include plug, lighting and other loads that are found in the apartments.

[16] Summer peak demand performance cannot be evaluated for modeled performance due to fact that energy modeling is based on standard, prescribed temperature values, whereas utility peak timing is influenced significantly by actual local weather conditions. Modeling data did show that it was highly likely that enough PV was installed to lower peak demand below the ZENH threshold.

[17] Summer peak demand performance cannot be evaluated for modeled performance due to lack of consistency between utility peak timing and weather data in the simulation environment. That is, energy modeling is based on standard, prescribed temperature values, whereas utility peak timing is influenced significantly by actual local weather conditions.

3.1.2. Business Model Implications

The most important operational consideration for the ZENH affordable housing business model is not whether the PIER project criteria were met but rather, whether the modeled financial scenarios and expected performance goals were actually delivered. Actual performance versus expected performance is the criterion by which other affordable housing developers and their financial partners will judge the success or failure of the project as a whole. With few exceptions, the projects delivered the performance and financial benefits that were modeled and expected. The ZENH project team can confidently say that on this score the projects delivered as advertised and has full confidence in recommending these strategies to other affordable housing developers.

Solara: Expectations vs. Performance

Table 13 shows a comparison of expected and actual performance on a number of key characteristics that have the potential to impact the ZENH affordable housing business model. When examining both modeled and monitored performance for electricity, it is important to understand the projected reductions for each fuel type modeled, not simply overall Title 24 performance. At Solara, the majority of the better-than-code performance in the modeling exercise resulted from energy efficiency measures targeted at reducing space heating and domestic hot water (natural gas) fuel use. When only those measures targeted at electricity consumption are considered (in this case, reducing cooling energy use), Solara would be expected to use 8.5% less electricity than the baseline community. However, for the monitoring period, Solara gross electricity consumption was approximately 16% higher than the baseline community when normalized for square footage. Potential explanations for this phenomenon include these: (1) differences in billing methodologies, whereby Solara residents do not pay directly for their utilities and the baseline residents do, with residents receiving less direct feedback on their electricity use, and (2) differences in the type of fuel used for cooking, whereby Solara uses electricity and Hillside uses natural gas.

Table 13: Comparison of 12-month apartment average modeled and monitored data at Solara

Category	Modeled	Monitored	Monitored Performance vs. Modeled
Gross Electricity Consumption (kWh)	3612.4	3709.6	3%
PV Production (per kWDC installed) (kWh)	1351.0	1477.3	9%
Net Electricity Consumption (kWh)	675.9	480.7	-29%

Modeling data did show that it was highly likely that enough PV was installed to lower peak demand below the ZENH threshold.

Electricity Cost ($/apartment)	$132.20	$125.55	-5%

Solara: Energy Cost and Usage Evaluation

When compared to the baseline apartments, net electricity costs and consumption for the Solara apartments are significantly less for the year (Table 14 and Table 15). Note that the lower costs are less prominent when normalized by square foot (SF) or bedroom (BR). The gross usage and cost indicate that the electricity usage at Solara is significantly higher than Hillside when PV production is not considered.

Table 14: Comparison of annual electricity costs at Solara and Hillside

	Solara		Hillside (Baseline)	Reduction from Baseline	
	Net (With PV)	Gross (Without PV)		Net (With PV)	Gross (Without PV)
Average Electricity Cost – *per Apartment Unit*	$ 125.55	$ 546.56	$390.70	68%	-40%
Average ECI[18] – *per 1000 square foot (SF)*	$ 145.03	$ 631.39	$383.77	62%	-65%
Average ECI – *per Bedroom (BR)*	$ 59.58	$ 259.38	$151.94	61%	-71%

Table 15: Comparison of annual net and gross total energy consumption at Solara and Hillside

PV

	Solara (kWh)		Hillside (Baseline) (kWh)	Reduction from Baseline	
	Net (With PV)	Gross (Without PV)		Net (With PV)	Gross (Without PV)
Average Consumption - *per Unit*	480.7	3709.6	3693.7	87%	0%
Average EUI - *per 1000 square foot (SF)*	477.7	4097.1	3655.4	87%	-12%
Average EUI - *per Bedroom (BR)*	228.1	1760.5	1458.0	84%	-21%

production for each unit is relatively consistent, but the consumption of each unit varies widely. Specifically, the coefficient of variation[19] of gross consumption (kWh) is 0.29, double that of PV production (kWh per kW DC installed) which has a coefficient of variation of 0.12. Furthermore, the individual gross consumption per bedroom ranges anywhere from 668.7 kWh to 4557.4 kWh, which represents almost an order of magnitude variation. This suggests that individual occupant behavior has a significant impact on energy use and cost in zero energy home units.

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[18]. Electricity Cost Intensity – a measure of normalized electricity cost per square foot or per bedroom.

[19] Coefficient of variation (CV) is a dimensionless measure of the dispersion associated with a set of data. This metric is defined as the standard deviation of the data set divided by the mean of the data set. Therefore, a data set with a larger amount of dispersion is characterized by a higher CV.

Solara: Electricity Rate and Schedule

Solara does not qualify for California Alternative Rates for Energy (CARE) discounts on electricity rates because tenants do not pay their own bills, even though each apartment is metered; the individual monthly bills go to the property management company. The CARE discount for low-income residents is 20%. If this 20% discount were applied to Solara, the electricity cost reduction per square foot compared to the baseline project would be 82%, would greatly exceed the 70% ZENH goal, and would meet the expected 85% modeled cost reduction.

Furthermore, the utility's minimum bill charge (approximately $5.17 per day monthly billing cycle or $62.05 per year) adds measurable costs to Solara's electricity bills. Even though some apartments at Solara are net exporters to the grid, they are still charged $62.05 per year to stay connected to the grid through minimum daily charges. SDG&E gives credit on an annual basis if the PV system generated more electricity than the customer used, but this generation credit cannot be used to pay down the minimum bill charge (nor will customers be reimbursed for their excess generation). As shown in Table 16, the total net annual cost of electricity to the monitored Solara units is approximately $3,515, but if the annual generation credit were applied to the minimum charges, the total net annual cost would be reduced by an estimated $526, or 15%. The impact of the minimum charge is especially significant due to the generally low net electricity usage at Solara. In fact, if generation credit could be applied to minimum charges, five Solara units would have no electricity costs at all, and an additional two units would be billed under $5 for the year.

Table 16: Annual electricity cost at Solara with and without annual generation credit being used to pay down minimum bill charges

Cost Category	Annual Electricity Cost		Cost Reduction
	Current Practice	With Generation Credit Applied to Minimum Charges	
Total	$ 3,515	$ 2,989	15%
per kWh	$ 0.26	$ 0.22	
per unit	$ 125.55	$ 106.74	
Per 1000 SF	$ 145.03	$ 123.31	
Per Bedroom	$ 59.58	$ 50.66	

Note: Data for only the 28 monitored units have been included.

Los Vecinos: Expectations vs. Performance

The comparison of modeled performance to observed performance for the entire six month monitoring period is shown in Table 17. The data suggest that both monitored gross and net consumptions are significantly lower than expected. This is largely due to overestimating unregulated loads (e.g., plug loads, lighting, and appliances) and underestimating PV performance during modeling.

Table 17. Comparison of six-month apartment average modeled and monitored data at Los Vecinos

	Modeled	Monitored	Monitored Performance vs. Modeled
Gross Electricity Consumption (kWh/Bedroom)	607.2	509.4	-19%
PV Production (per kWDC installed) kWh	697.5	801.1	13%
Net Electricity Consumption (kWh/Bedroom)	133.5	-34.5	-126%

Natural Gas Consumption (therms/bedroom)	29.2	21.8	-34%

Natural gas consumption was significantly lower than predicted from the energy models. This could be due to a number of factors including deviations from hot water consumption assumptions in the Title 24 energy modeling rule set and potentially inaccurate heating assumptions is the rule set for hydronic heating applications. Furthermore, the study period did not fully capture half of the heating season which is at its peak during January and February. As a result, the observed gas consumption data is likely to be even less than modeled because the time period observed includes fewer heating months than were modeled.

Los Vecinos: Energy Cost and Usage Evaluation

When compared to the baseline apartments, as shown in Table 18 and Table 19, net electricity costs and consumption for the Los Vecinos apartments are significantly less for the six month period. Note that the difference in cost is less prominent when normalized by bedroom. The gross usage and cost indicate that the gross electricity usage (without PV production) at Los Vecinos is actually higher than Beyer.

Table 18: Comparison of six-month electricity costs at Los Vecinos and Beyer

	Los Vecinos		Beyer (Baseline)	Reduction from Baseline	
	Net (With PV)	**Gross (Without PV)**		**Net (With PV)**	**Gross (Without PV)**
Average Utility Cost – *per Unit*	$39.65	$113.72	$134.13	70%	15%
Average ECI – *per Bedroom (BR)*	$19.36	$55.54	$50.81	62%	-9%

Table 19: Comparison of six month net and gross total energy consumption at Los Vecinos and Beyer

	Los Vecinos (kWh)		Beyer (Baseline) (kWh)	Reduction from Baseline	
	Net (With PV)	**Gross (Without PV)**		**Net (With PV)**	**Gross (Without PV)**
Average Consumption - *per Unit*	-70.7	1043.1	1209.4	106%	14%
Average EUI - *per Bedroom (BR)*	-34.5	509.4	458.1	108%	-11%

PV production for each unit is relatively consistent, but the consumption of each unit varies widely. Specifically, the coefficient of variation[20] of gross consumption (kWh) is 0.52, more than seven times that of PV production (kWh per kW DC installed) which has a coefficient of variation of 0.07. Furthermore, the individual gross consumption per bedroom ranges anywhere from 328 kWh to 2397 kWh, which represents almost an order of

[20] Coefficient of variation (CV) is a dimensionless measure of the dispersion associated with a set of data. This metric is defined as the standard deviation of the data set divided by the mean of the data set. Therefore, a data set with a larger amount of dispersion is characterized by a higher CV.

magnitude variation. This suggests that individual occupant behavior has a significant impact on energy use and cost in zero energy home units.

Los Vecinos: Electricity Rate and Schedule

Two items greatly impact the analysis of electricity rates and schedules at Los Vecinos. First is whether residents are eligible for and have signed up for CARE discounts. Second is the minimum monthly fee that each apartment is charged regardless of net electricity usage.

Residents at both Los Vecinos and Beyer are billed for electricity according to the Residential Electricity Service rate schedule (schedule DR), but the ratio of families receiving the 20% CARE discount varies greatly. Over a quarter of surveyed Los Vecinos residents are not enrolled in CARE and are therefore not receiving a 20% utility bill discount. As seen in Table 20, residents enrolled in CARE receive approximately ten dollars in discounts from their electricity bill every six months.

Table 20: Electricity CARE enrollment at Los Vecinos and Beyer

	Electricity	
	Los Vecinos	Beyer
Number of Units Surveyed	40	34
Number of units enrolled in CARE for electricity account	29	32
Percentage enrollment in CARE for electricity account	73%	94%
Average ECI discount with CARE ($/Bdrm)	$4.84	$12.70
Average Utility Cost discount with CARE ($/unit)	$9.91	$33.53

The CARE program has more stringent requirements for income than either of the communities require for residency. In other words, having an apartment at Beyer or Los Vecinos does not necessarily guarantee eligibility for discounted utility rates. Management at Los Vecinos, however, estimates that 85% of residents are eligible for the program. Therefore, enrollment rates vary not only because of potentially different income levels at each community, but also because not all eligible Los Vecinos residents have chosen to apply for CARE.

In order to provide a one-to-one comparison, analysis of cost in this section of the report assumes that all residents at both communities receive the discounted electricity rates associated with the CARE discount (Schedule DR-LI). Using unequal CARE enrollment rates would inaccurately characterize electricity use, and furthermore, would be applicable only for the current mix of residents, as the rate of enrollment in CARE at each community will fluctuate over time.

At the same time, minimum bill charges at Los Vecinos have a significant impact on electricity rates. SDG&E customers are charged $5.17 per month for months when electricity purchases do not exceed $5.17 per month. Because most Los Vecinos residents are very low if not negative consumers, the minimum bill charge is often the only cost associated with their electricity accounts. After applying CARE discounts, the six month minimum charge at Los Vecinos totals $24.75, which accounts for 62% of observed electricity charges.

Combining the effect of CARE and minimum bill charges shows that they significantly impact the effective electricity cost rate at Los Vecinos. The effective electricity cost rate is defined simply as the average cost of each unit of electricity ($/kWh). At Los Vecinos, the effective electricity cost rate is calculated to be $0.19/kWh, almost double the $0.11/kWh observed at Beyer.

To better illustrate the isolated contribution of each aforementioned billing factor, Figure 3 summarizes the breakdown of effective electricity cost rates at Los Vecinos. Case 1 represents the breakdown of the effective cost rate if Los Vecinos residents were on standard (non-low income) electricity rates without net metering. When the CARE discount and net metering setup is applied in Case 2, the effective rate drops by 20% or $0.05/kWh.

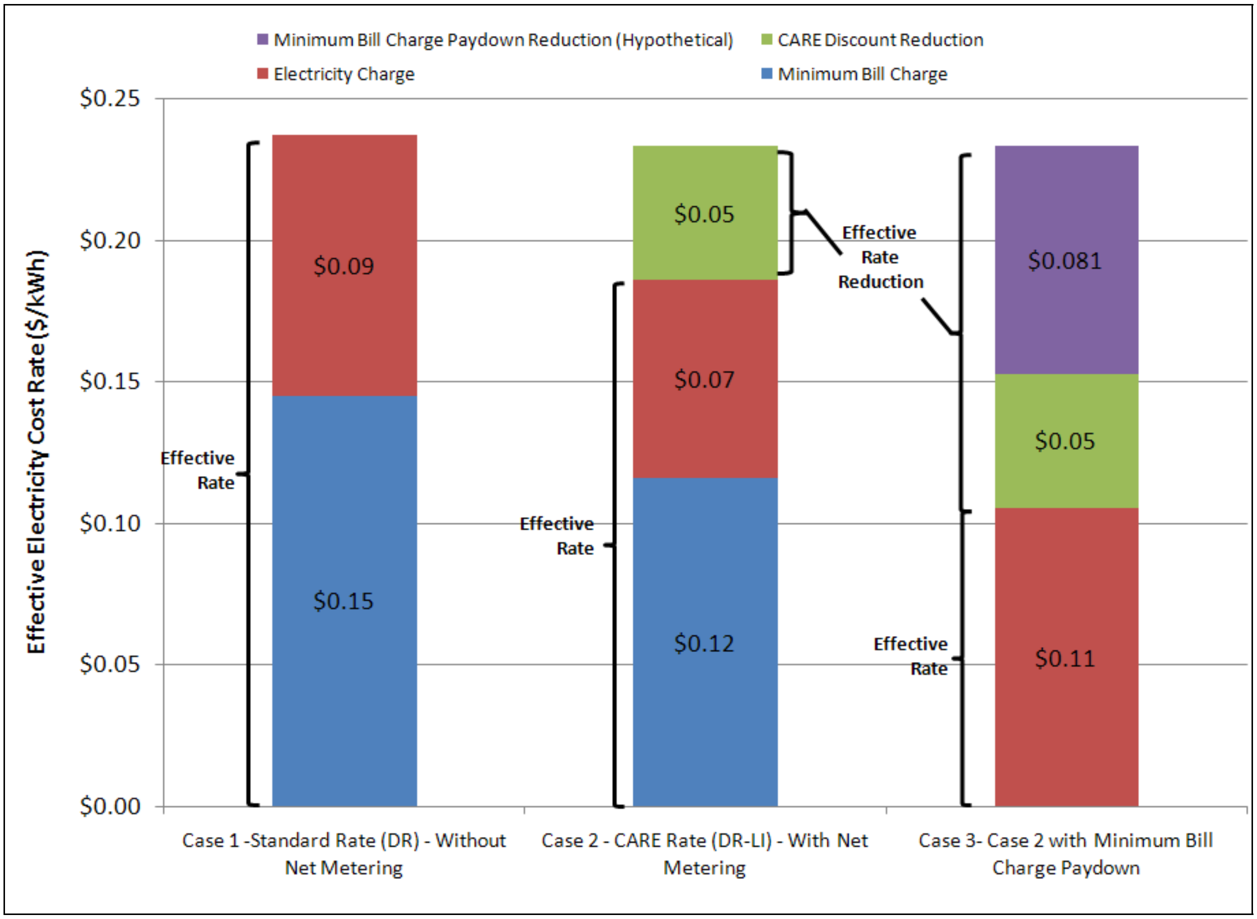


Figure 3. Effective electricity cost rate ($/kWh) at Los Vecinos for various billing scenarios.

By far, the largest portion of the effective cost rate is made up of minimum bill charges. In both Case 1 and Case 2, the minimum bill charge accounts for over 60% of the effective cost rate. Beyer residents almost always purchase enough electricity to avoid these costs, but most Los Vecinos residents cannot avoid the minimum charges during months where PV production is high and consumption is low.

As seen in Case 3, however, if earned generation credits could also be used to pay for minimum bill charges, Los Vecinos residents would, on average, be able to completely offset this minimum charge. As a result, their effective electricity cost rate would then be reduced to the same cost rate paid by Beyer residents (i.e., $0.11/kWh). This minimum bill charge "pay down" scenario is purely hypothetical but illustrates not only the weight of minimum bill charges, but also the significant value of generation credit that cannot currently be applied to energy bills.

3.2. Outreach and Technology Transfer

3.2.1. Affordable housing and solar industry market outreach

Using lessons learned during the finance, design, construction and operations of the two built projects, the ZENH research team engaged in a number of outreach efforts aimed primarily at affordable housing developers. In addition, the team conducted outreach to the solar industry to educate them about the business opportunities in the affordable housing market. The outreach efforts included speaking at conferences and training workshops, publishing case studies, producing short films, maintaining a website with specific information about solar and affordable housing, and building a Solar Affordable Housing Assessment Calculator.

The research team members spoke about ZENH strategies and project specifics at the conferences and workshops listed in Table 21 during the duration of the research effort.

Table 21: Conferences and Workshops with ZENH strategies presented

Month/Year	Conference	Approximate Number of Attendees	Type of Attendee
10/2005	Southern California Association of Non-Profit Housing	35	Affordable Housing Developers, Funders, Designers
10/2005	San Diego Housing Federation	50	Affordable Housing Developers, Funders, Designers
10/2005	Non-Profit Housing of Northern California	75	Affordable Housing Developers, Funders, Designers
10/2005	Housing Leadership Conference of San Mateo County	25	Local Government Funders, Affordable Housing Developers
11/2005	AIA Housing Committee	30	Affordable Housing Designers
05/2006	Municipal Green Building Conference and Expo	40	Local Government Funders, Utility Personnel, Affordable Housing Designers
08/2006	ACEEE Summer Study on Energy Efficiency	40	Building Energy Efficiency Experts
09/2006	Southern California Association of Non-Profit Housing	35	Affordable Housing Developers, Funders, Designers
10/2006	San Diego Housing Federation	50	Affordable Housing Developers, Funders, Designers
04/2007	Housing California: Luncheon Keynote	500	Affordable Housing Developers, Funders, Designers
09/2007	Non-Profit Housing of Northern California	75	Affordable Housing Developers, Funders, Designers
10/2007	San Diego Housing Federation	50	Affordable Housing Developers, Funders, Designers
10/2007	California Housing Finance Agency	50	Affordable Housing Funders
04/2008	Housing California: Full Day Training Workshop	35	Affordable Housing Developers, Funders, Designers
09/2008	Non-Profit Housing of Northern California	75	Affordable Housing Developers, Funders, Designers

10/2008	Solar Power International (1)	250	Solar Industry
10/2008	Solar Power International (2)	150	Solar Industry
10/2008	San Diego Housing Federation	50	Affordable Housing Developers, Funders, Designers
01/2009	Rahus Institute Solar Forum	75	Solar Advocates
04/2009	Housing California	25	Affordable Housing Developers, Funders, Designers
04/2009	National Apartment Association Green Conference	50	Multifamily Housing Industry
05/2009	California Redevelopment Association: Full Day Training	25	Affordable Housing Funders
06/2009	HUD Energy Efficiency Seminar	100	Affordable Housing Developers, Local Public Agencies
10/2009	San Diego Housing Federation	40	Affordable Housing Developers, Funders, Designers
10/2009	Solar Power International	300	Solar Industry
11/2009	Southern California Association of Non-Profit Housing	20	Affordable Housing Developers, Funders, Designers

The ZENH program team wrote and published case studies for each of the two projects. Appendices C and D contain copies of those case studies. They are also available for download at www.globalgreen.org/greenurbanism/affordablehousing/.

The team also produced two short films using film and data collected at the two projects. The first film, lasting just over nine minutes and produced in 2007, was aimed at affordable housing developers as an introduction to PV technology, how it can be incorporated into an affordable housing project, and the business model supporting ZENH strategies. Figure 4 is a screen shot of the first film. It can be viewed online at www.globalgreen.org/greenurbanism/zero/.

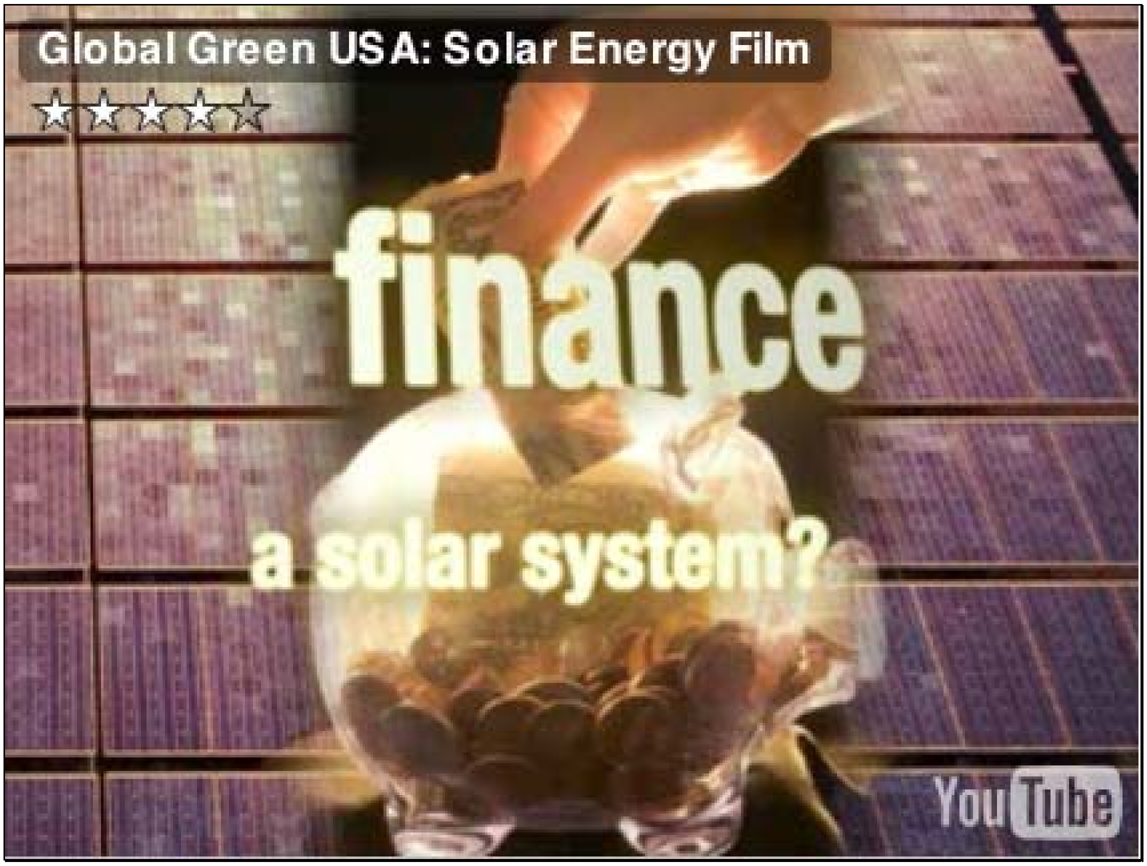


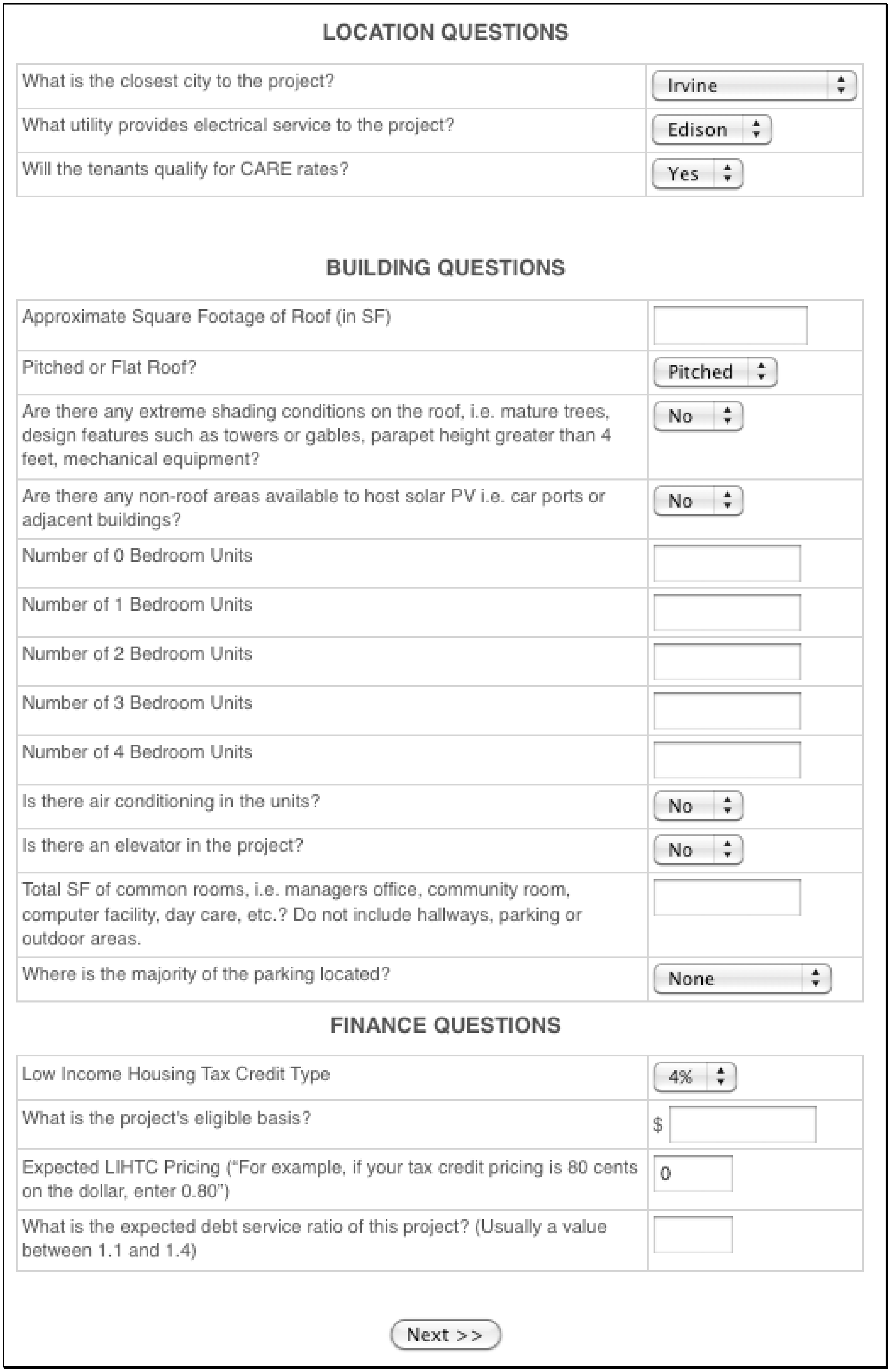
Figure 4: Screen shot of film introducing solar to affordable housing developers

The second film, lasting five minutes and produced in 2010, is a narrative case study of Solara and Los Vecinos, incorporating interviews with project participants and residents and focusing on financial and environmental results. Figure 5 is a screen shot of the second film. It can also be viewed online at www.globalgreen.org/greenurbanism/zero/.

Figure 5: Screen shot of "Two Solar Communities" case study film

Project team leader Global Green established a net zero energy affordable housing page on its website at www.globalgreen.org/greenurbanism/zero/. In addition to the case studies and films, the site provides information on the various incentives and rebates that an affordable housing developer could take advantage of when attempting to design and finance a ZENH project.

A key element of this webpage is the "Solar Affordable Housing Design Calculator." This calculator, available at www.globalgreen.org/solarcalculator/, is an interactive tool that assists affordable housing developers and their design and finance teams assess various options for incorporating solar photovoltaic systems into their California-based Low Income Housing Tax Credit developments. The assessment marries design and finance considerations by asking questions intended for the schematic design phase of a development project. The calculator produces a variety of financial scenarios that developers can incorporate into their preliminary pro-formas and tax credit applications, as well as photovoltaic sizing options that design teams can use to issue RFPs for solar design/build services. Figure 6 is a screen shot of the questions that the calculator asks.



LOCATION QUESTIONS

What is the closest city to the project?	Irvine
What utility provides electrical service to the project?	Edison
Will the tenants qualify for CARE rates?	Yes

BUILDING QUESTIONS

Approximate Square Footage of Roof (in SF)	
Pitched or Flat Roof?	Pitched
Are there any extreme shading conditions on the roof, i.e. mature trees, design features such as towers or gables, parapet height greater than 4 feet, mechanical equipment?	No
Are there any non-roof areas available to host solar PV i.e. car ports or adjacent buildings?	No
Number of 0 Bedroom Units	
Number of 1 Bedroom Units	
Number of 2 Bedroom Units	
Number of 3 Bedroom Units	
Number of 4 Bedroom Units	
Is there air conditioning in the units?	No
Is there an elevator in the project?	No
Total SF of common rooms, i.e. managers office, community room, computer facility, day care, etc.? Do not include hallways, parking or outdoor areas.	
Where is the majority of the parking located?	None

FINANCE QUESTIONS

Low Income Housing Tax Credit Type	4%
What is the project's eligible basis?	$
Expected LIHTC Pricing ("For example, if your tax credit pricing is 80 cents on the dollar, enter 0.80")	0
What is the expected debt service ratio of this project? (Usually a value between 1.1 and 1.4)	

Next >>

Figure 6: List of questions asked by Solar Affordable Housing Design Calculator

3.2.2. Regulatory efforts to improve the business model

Two important regulatory changes in California that improve the viability of the ZENH affordable housing business model – one financial and the other technical – were significantly informed and enabled by the lessons learned from the two ZENH projects. The ZENH project team participated actively in both of these successful reform efforts.

Utility Allowance Calculation

As described in Section 2.3 on the financing package necessary to implement ZENH strategies, affordable housing developers need to be able to capture a portion of the lower utility bills in order to leverage financing. Monthly rents in affordable housing are set by a formula that includes an allowance for utility costs. Local Housing Authorities typically set this allowance based on a survey of existing properties that in many cases use much more energy than new construction built to strict energy codes and do not include on-site generation technologies. This leads to a situation whereby the utility allowance for tenants does not correlate with the lower utility bills that would be expected from a ZENH project.

Until 2007, efforts to create energy efficient utility allowances that took into account project specifics and/or new energy efficient construction were spotty and inconsistently implemented throughout the state, and developers were largely unable to share in the benefits from additional energy efficiency and solar investments. Solara drove home this point, whereby the only way the project developer could finance the additional investments was to assume responsibility for all utility bills by including a fixed surcharge in the rent. This strategy was financially risky and likely led to some of the high gross electricity consumption at the project.

With assistance from Global Green and Solara's developer in publicizing the huge barrier this utility allowance issue was causing for other affordable housing developers, the Energy Commission funded KEMA Energy to develop the California Utility Allowance Calculator (CUAC), which uses Title 24 modeling and other inputs to generate a project-specific utility allowance pegged to actual project characteristics. The CUAC has been accepted by the California Tax Credit Allocation Committee as an approved methodology for setting utility allowances for Low Income Housing Tax Credit projects in the state and has been used extensively by projects since the 2009 affordable housing development cycle. Use of the CUAC allows both tenants and owners to share in the financial benefits of ZENH strategy implementation and removes one of the key financial barriers previously faced by project developers.

Virtual Net Metering

California regulations require that the vast majority of multifamily buildings have their units individually metered for electricity.[21] This regulation has been shown to be effective in promoting lower energy consumption in multifamily buildings by providing occupants of individual apartments monthly feedback on their electricity consumption and financial penalties for excess consumption. When net metering regulations were promulgated in California, they treated multifamily buildings the same as single family residences, requiring a separate net metering agreement, inverter, and utility disconnect for every meter.

The effect of these regulations on Solara and Los Vecinos is that each residential unit in these projects has its own solar array, inverter, utility disconnects, and utility net metering agreement. This situation

[21] The few exceptions are some Single Room Occupancy buildings (classified as hotels) and projects served by some municipal utilities.

- added approximately $1000 per unit to the cost of the PV system
- added significant design complexity in the wiring of the various PV systems
- forced the design teams to give up space in a tight urban environment to large inverter rooms
- contributed to significant ventilation and heat challenges from placing so many inverters in one enclosed space; Los Vecinos even added air conditioning to defuse potential inverter-related heat problems
- cost both project developers significant amounts of administrative time with their utility to set up and administer dozens of separate net metering accounts; to this day Los Vecinos staff still face issues with individual PV system production being incorrectly credited by their utility.

Tours of and publicity about the projects showing both the design complexity and financial penalty paid by project developers, plus ongoing work by Global Green staff with San Diego Gas & Electric since 2006, have helped to give momentum to a new Virtual Net Metering (VNM) tariff that was approved by the California Public Utilities Commission in mid 2009. The VNM tariff allows affordable housing projects to install one master meter and inverter to measure the amount of electricity generated by the photovoltaic system. Individual apartments are still individually metered for consumption, but their monthly utility bills automatically are credited with a percentage of the electricity generated by the photovoltaic system.

This new VNM tariff removes some of the design complexity from ZENH buildings, while lowering both construction and administrative costs. Together with the CUAC described above, it also allows for a customizable set of financial and design parameters for very low energy buildings that, for reasons of cost limitations or design considerations, cannot reach full ZENH status but desire to power a significant portion of their apartments' electricity demand with on-site generation.

4.0 Conclusions and Recommendations

4.1. Conclusions

Based on the results of the Solara and Los Vecinos developments, the ZENH affordable multifamily team reached the following main conclusions regarding financing, design, analysis, and applicability of ZENH strategies within an affordable housing business model.

4.1.1. ZEHN Affordable Projects Are Financially Viable

Projects that meet net zero electricity goals can be financed, given the current energy and on-site generation incentive structure and the affordable housing regulatory and financing framework. Through the combination of affordable housing tax credits, federal solar investment tax credits, state rebates for energy efficiency and solar installations, and additional debt leveraged from energy cost savings, developers can fully cover the first cost of constructing a net zero electricity building. Volatility in the tax credit and mortgage market and decreasing rates of on-site generation incentives may make these types of projects more difficult to finance in the future, but the basic financial package described in this report is feasible within the typical structure of affordable housing developments.

4.1.2. Energy Cost Modeling Can Be Sufficiently Accurate

It is possible for project teams to project energy consumption and generation with the degree of accuracy necessary for financial underwriting, as demonstrated by the comparison of energy cost projections with actual operation costs for Solara and Los Vecinos. Being able to estimate future utility costs with a reasonable degree of accuracy is critical to the net zero affordable housing business model. The primary issue relates to being able to accurately adjust utility cost assumptions. In the low-income market, housing costs are considered to include rent and utilities. By reducing the utility portion, developers can increase the rent component, while still maintaining total housing costs within the affordable range. Project teams need to be fully informed and use caution in how they translate these projected energy savings into projected cost savings due to the restrictions on receiving credits for excess generation and daily charges for utility hook-ups regardless of the overall project's annual net electricity consumption. By using a combination of state approved software, daily charge rates from the utility, information on occupant behavior, and careful analysis of expected plug loads, it is possible to predict the energy savings with a sufficient degree of accuracy to support utility allowance and overall operating cost adjustments.

4.1.3. Taller Buildings Pose a Challenge

Based on the outcomes of this research project, there appears to be a height limit of three to four stories on residential buildings seeking to achieve net zero electricity goals using current technology.

As buildings increase in height and dwelling unit density, overall building energy use increases while the space on the roof area available for renewable energy systems remains constant. Los Vecinos, a three story building, has 100% fluorescent lighting, all Energy Star appliances, and no mechanical cooling, yet still was unable to fit a large enough photovoltaic system on the roof to meet the net zero targets (requiring use of an adjacent car port). Advances in photovoltaic efficiency and lighting electricity consumption, along with more stringent appliance standards to lower plug load, will all be necessary if buildings over four stories are to meet future zero energy requirements. These advances are even more crucial as zero net energy (as compared to net zero electricity) criteria begin to include energy used for space heating and domestic hot water, which is typically natural gas. Meeting a future zero net energy standard will likely require solar thermal and/or additional photovoltaic capacity to reduce or offset the natural gas use, further increasing the roof space requirements for renewable energy systems. Advances in energy efficiency and renewables are also necessary if California communities are to both build net zero energy buildings and still be able to achieve the residential unit density (and often corresponding building heights) necessary to construct the walkable transit-oriented communities that are crucial to reducing transportation-based greenhouse gas emissions statewide.

4.2. Recommendations

While the main components of a viable long-term business model for net zero affordable housing are in place, there are a number of opportunities to clarify, strengthen, and expand upon the business model.

4.2.1. Defining Zero Net Energy

As California moves towards a code requirement of zero net energy for all new residential buildings by 2020, it is crucial to begin a robust debate about the definition of zero net energy and the means by which it should be achieved. The results of this research project have taught us that the optimal mix of energy efficiency measures and on-site electricity generation needed to meet zero net energy goals is highly dependent on building type, climate zone, system selection, and rebate and incentive levels. In addition, zero net energy (in absolute kBTU terms) does not necessarily translate into zero net energy cost. Thus the actual reduction in utility bills may be less than the overall reduction in energy usage. Finally, the de facto restriction on building height that zero net energy currently implies, could have important land use consequences that may negate the greenhouse gas emissions reductions zero net energy buildings will bring. These variations in climate, building design, cost, incentives and land use implications all need to be considered when determining the ultimate code definition of zero net energy.

4.2.2. Advances in Energy Efficiency

In order for zero energy multifamily buildings to be constructed on a wider scale, plug load and lighting consumption need to be reduced. This reduction can most effectively occur through increasing efficiency requirements on particular pieces of equipment and lighting fixtures rather than through whole building design.

With air conditioning such an important load in many California climates, the Energy Commission could advance the effort to create zero net energy homes by working to eliminate this load altogether in addition to increasing cooling efficiency standards. More research on natural ventilation strategies in transitional climate zones, together with developing a methodology within the Title 24 rule-set allowing mechanical cooling to be removed without paying a penalty on efficiency calculations, would be a step in the right direction.

More research is also needed on strategies that will predictably affect occupant behavior. The wide variance in gross electricity consumption at both Solara and Los Vecinos suggests that design strategies are only part of what is necessary to have zero net energy designed buildings deliver on their intended performance.

4.2.3. Financial Considerations and Rebates

The main driver of most low-income housing developments is federal low-income housing tax credits. There has been significant turmoil in the financial markets in general over the past three years and in the tax credit markets in particular. The most immediate outcome has been a reduction in the amount that investors are willing to pay to be able to take advantage of tax credits, which in turn places greater constraint on affordable housing project budgets. Because energy efficiency and on-site generation do carry some additional first costs, a more constrained budget environment makes the investments needed to achieve zero energy more difficult to finance. In this more cautious financing environment, it can be expected that some developers will choose to pursue less aggressive projects, rather than the full suite of strategies and systems needed to achieve zero net energy.

This reluctance to build zero energy buildings should not, however, be seen as evidence that the net zero business model is not viable. Instead, the recommendation is to maintain the core components of the business model, especially the New Solar Homes rebates, the utility allowance adjustment, and the other incentive for energy efficiency and on-site generation offered by the California Tax Credit Allocation Committee. When the low-income housing tax credit market stabilizes and tax credit pricing improves, the viability of zero net energy for a significant portion of affordable housing built in California should be restored.

In the meantime, the state should continue efforts to reduce the cost and effort in designing zero net energy projects. One of the most valuable resources would be a residential Title 24 model output that includes a calculation of total expected energy use, including lighting and non-regulated loads, and an estimate of the associated costs for natural gas and electricity.

4.3. Benefits to California

The following are the key benefits to the state generated by PIER funding from this Global Green zero energy affordable housing research:

- The PIER research demonstrates the technical and financial feasibility of zero net energy affordable housing developments. While the concept of zero energy affordable housing had been discussed for several years in the green building and affordable housing communities, the built examples were of either high level energy efficiency projects or developments with photovoltaic systems serving the common area only. The Global Green research project proves the ZEHN affordable concept by providing two real-world examples. This demonstration of feasibility benefits the state by setting a new standard for what is possible within the parameters of the affordable housing design and development model. The project also provides a practical reference for both state policymakers and staff in the housing, energy, and building codes agencies.
- The PIER research provides valuable data on project performance. The monitoring data from the two demonstration projects serves as a valuable resource for Energy Commission staff and other energy stakeholders in the state. The data demonstrated the challenges associated with predicting actual energy costs from the existing energy performance models. The monitoring data also supported or suggested additional research needs related to energy cost projections and more effective ZENH project designs.
- The PIER research made recommendations for changes related to regulations governing the housing finance, energy service, energy code, and building code elements of zero energy affordable housing projects. Key regulation changes that either emerged directly from or were influenced by the research project are the California Utility Allowance Calculator and the approval of virtual net metering provisions. Both of these regulatory changes help lower costs of ZENH multifamily projects. In addition, the experiences from the ZEHN affordable projects provided valuable insight into the development of the New Solar Homes rebate program for affordable housing.

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Finally, the PIER research supports and helps provide clarity to the specific strategies and the serious challenges that can emerge in achieving the long-term state policy objectives of zero energy housing by 2020. SOLARA

PIER INTERIM PROJECT REPORT

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California Energy Commission

Public Interest Energy Research Program

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Solara One-Year Monitoring Report: An Affordable Multifamily Zero Energy New Home Project is an interim report for the Affordable Multifamily ZENH project (contract number 500-04-023, conducted by Global Green USA. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

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Abstract

The state of California has set aggressive targets for the development of zero net energy buildings over the coming decades. In order to assess the technical and financial viability of zero net energy building designs, the California Energy Commission developed a Zero Energy New Homes (ZENH) research program. Under this program, the Commission contracted with Global Green USA who, in partnership with Community Housing Works, developed the Solara Zero Energy Affordable Multifamily Housing complex in Poway, California. The ZENH program goals are for the homes to (1) perform 25% better than Title 24 (2005) energy standards, (2) have a 70% reduction in electricity costs for the occupants compared to standard housing, (3) have a summer peak demand of 1 kW or less, and (4) have an incremental capital cost, after rebates and incentives, of less than $5,000 per housing unit.

Construction of the Solara project was completed in March of 2007 and included numerous energy efficiency measures and solar photovoltaic systems in an effort to achieve the ZENH program goals. Global Green and its partners deployed a detailed monitoring and evaluation process to assess actual performance with respect to the goals, with a monitoring period from August 2007 through July 2008. The project team monitored energy use both at Solara and at a nearby community (Hillside) with similar characteristics, such that Solara's performance could be compared with "typical" construction practices.

ecause Solara was originally designed under the 2001 Title 24 Energy Code, the project did not attain the 25% modeled energy use reduction target with respect to 2005 Title 24 (although computer modeling showed that the project exceeded 2005 standards by approximately 15% and 2001 energy standards by 40%). Direct comparison with the baseline community shows that electric utility costs were reduced by 62% when normalized by square footage, slightly under the program goal of 70%. However, when differences in billing structures and cooking fuels are adjusted, the project team projects that Solara could have more than an 80% reduction in electric utility costs when compared with the baseline. The Summer Peak Demand of each Solara apartment is well below the program goal of 1 kW throughout the year. In fact, Solara is a net exporter of electricity at the time of the local utility peak for nine out of twelve months of the year, including the annual system peak in the summer.

The fourth ZENH goal of meeting the energy-related targets with a net incremental cost of less than $5,000 per unit was not covered by the post-occupancy monitoring activities and will be addressed comprehensively for Solara, and another Global Green ZENH affordable housing project, Los Vecinos, in the final report to the Energy Commission due in spring of 2010.

Keywords:

Zero net energy, zero energy, photovoltaics, PV panels, energy efficiency, affordable housing, multifamily housing, monitoring and verification

Executive Summary

Introduction

The state of California has developed ambitious energy consumption reduction targets for the new construction market over the coming decades. In order to explore the financial and technical feasibility and barriers to these goals, the California Energy Commission developed a Zero Energy New Homes (ZENH) research program with the following goals: develop housing units that (1) perform 25% better than Title 24 (2005) energy standards, (2) have a 70% reduction in electric utility costs, (3) have a summer peak demand of 1 kW or less, and (4) have an incremental capital cost, after rebates and incentives, of less than $5,000.

In order to develop a business case for zero energy affordable housing, the Commission contracted with a team led by Global Green USA to develop two Zero Energy New Home affordable housing projects in cooperation with two non-profit developers. The first project, Solara, opened in the spring of 2007 and is the subject of this report. A second project, Los Vecinos, was completed in spring 2009 and is the subject of a separate monitoring report.[1]

In addition to monitoring energy use for half of Solara's apartments (28 of 56 units), the project team monitored four units of a nearby affordable housing complex (Hillside) built by the same developer with similar attributes, as a "baseline" case. However, the baseline community incorporates energy efficiency measures that helped it exceed Title 24 (2001) by 28% (as modeled), and as such, comparison with Hillside does not represent a comparison with a minimally code-compliant project.

Purpose and Project Objectives

The purpose and objectives of monitoring and evaluation activities documented in this report are to analyze Solara to determine if the project met the ZENH program goals (excluding the incremental capital cost goal).

Conclusions

Zero Energy New Homes Goal Performance

The Solara complex was designed and constructed to exceed the 2001 Title 24 energy code by more than 40%, translating into performance that is approximately 15% better than 2005 Title 24. Therefore, the program goal for exceeding 2005 energy code by 25% was not attained.

Based on the monitoring period analyzed in this report (August 2007 through July 2008), electricity bills for the Solara project were reduced by 62% when normalized for square footage, slightly below the program goal of 70%. However, there are significant differences in both the design and operation of Solara compared with Hillside that impact this goal, including these:

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[1] See Do, P. and J.Meacham (CTG) and T. Bardacke (Global Green USA). 2010. *Los Vecinos Monitoring Report*. California Energy Commission, PIER Building End-Use Efficiency Program.

- The use of electric appliances at Solara and gas appliances at Hillside for cooking, and
- Differences in utility bill payment methods: rent at Solara includes utilities while tenants at Hillside pay their utility bills directly to San Diego Gas & Electric (SDG&E).

Adjusting for these differences, Solara is estimated to exceed the electricity cost reduction goal, achieving more than an 80% reduction in electricity costs.

The average peak demand of each of the monitored Solara apartments was well below the ZENH program goal of 1 kW, and the time of day of peak electricity use at Solara was later than the utility's peak. For nine out of the 12 months monitored, the Solara apartments were exporting power to the grid during SDG&E's peak demand period, including the time during the SDG&E annual system peak in the summer. This suggests that the complex is reducing grid congestion during the most critical peak demand period(s) of the year.

Comparison with Modeled Performance

The average per apartment energy consumption of Solara deviated from modeling projections by only 3%. PV system production was significantly higher than predicted. Net electricity consumption at Solara was significantly lower than predicted due to the increased production from the solar panels. Natural gas consumption was nearly three times higher than predicted, likely due to the centralized heating and hot water system that was not configured correctly during construction and not accurately accounted for in the energy modeling software, and due to SDG&E's actual billing rate (discussed below).

Total Site Energy Use and Cost Performance

Solara was observed to consume approximately 12% more *gross* electricity (i.e., not including PV production) than Hillside. However, if the data are adjusted to remove the estimated electricity use for cooking (because Hillside uses gas for cooking), Solara would be expected to use approximately 11% less gross electricity than Hillside. Additionally, if the electricity for cooking is removed from the observed results at Solara, the complex would be expected to be truly net zero with respect to electricity.

Natural gas consumption data were available for only seven of the twelve months of the monitoring period (January 2008 through July 2008). During this period, Solara's natural gas consumption was only 2% less than Hillside's. Therefore, *total site energy consumption* (natural gas and electricity) is only 31% less at Solara.

During the project, the research team discovered that Solara was on an inappropriate natural gas billing rate schedule, resulting in significantly higher per unit natural gas costs than at Hillside. (This is being addressed.) Additionally, because Solara's developer pays the gas bills, Solara is not eligible for low income rate structures. This results in per therm natural gas prices at Solara that are 43% higher than at Hillside. Consequently, *total annual energy costs* at Solara are only 14% less than Hillside's for the seven months ending July 2008.

Design and Operational Implications for Zero Energy New Housing

The project team observed that electricity consumption varied by nearly an order of magnitude (from lowest consumer to highest) on a per bedroom basis at Solara, suggesting that occupant behavior may have a significant impact on the success of zero energy housing.

The design of the centralized water heating systems at Solara resulted in significantly higher natural gas consumption than predicted by the energy modeling software. This may be due in part to state laws that require heating to be available year round that were not correctly implemented during the design and construction of Solara. As a result, the centralized hot water loop at Solara remains hot all year round, even in summer months.

The Solara project was focused on achieving zero net *electricity* consumption goals. In order to achieve zero net *energy* designs, projects will have to either deploy all-electric infrastructures with higher efficiency designs and appliances and/or larger solar PV systems or utilize solar thermal hot water systems for space heating and domestic water. However, particularly in multi-family housing, there may not be enough roof space available to accommodate net zero energy designs that address both electricity and natural gas use.

Recommendations

A number of key recommendations can be drawn from the conclusions:

4. Research is needed to understand the impact of utility billing structures, feedback devices, and other strategies for influencing occupant behavior in order to cost effectively achieve ZENH program goals.
5. More performance data are needed over a longer monitoring period to substantiate the utility grid peak demand implications of ZENH projects. Extended performance monitoring may facilitate a revaluation of current incentive structures for solar PV and ZENH projects based on their contribution to local grid congestion reduction.
6. More research is needed to understand optimized net zero energy designs for affordable and multi-family housing that consider total site energy consumption, in particular limitations to achieving zero net energy based on building form, height, and density.
7. While the apartment data collection systems used reliable hardware platforms, more research and development is needed for the supporting software systems that collect, organize, and display performance data.

Benefits to California

This project advances the understanding of the technical and policy issues surrounding ZENH project implementation. ZENH projects offer a number of potential benefits to the state:

- Decreased cost of living for income-qualified residents,
- Decreased utility grid congestion from strategically sited ZENH developments,
- Decreased total cost of electricity for rate payers due to decreased infrastructure costs that may result from future ZENH projects, and

- Incentives for developers to create more affordable housing with less environmental impact than traditional development.

1.0 Introduction

California energy policy has set a bold target for energy consumption reductions from new buildings, aiming for zero net energy consumption for all newly constructed residential buildings by 2020 and non-residential buildings by 2030. For the past several years, the California Energy Commission (Energy Commission) has been exploring the technical, financial, and regulatory feasibility of this goal through a Zero Energy New Homes (ZENH) effort, administered by the Commission's Public Interest Energy Research (PIER) program. The ZENH program has four main performance goals: develop housing units that (1) perform 25% better than Title 24 (2005) standards, (2) have a 70% reduction in electric utility costs, (3) have a Summer Peak Demand of 1 kW or less, and (4) have an incremental capital cost, after rebates and incentives, of less than $5,000.

Within the residential building sector, different building types and market niches face different issues when pursuing these ambitious energy targets and goals. Multifamily buildings, despite inherent environmental benefits of shared walls, smaller living spaces, and density levels that support public transit, face the challenge of having limited space for installing on-site generation technologies. And within the multifamily sector, affordable housing faces the challenge of simply securing enough funding to build much-needed units, let alone taking on the additional financial burden of pursuing zero energy strategies. While the long-term economic benefits of utility bill reduction for low-income tenants residing in zero energy affordable housing is particularly compelling, the financing and development model of affordable housing is completely different from that of market rate housing.

In order to further explore these issues and ultimately develop a business case for zero energy affordable housing, in 2005 the PIER Program awarded a team led by Global Green USA, a California-based non-profit environmental organization, a contract to develop two ZENH affordable housing projects in cooperation with two non-profit affordable housing developers. The first project, Solara, opened in the spring of 2007. A second project, Los Vecinos, is scheduled to be completed in the spring of 2009. Figure 1 shows an aerial photograph of Solara.

This report documents a year of monitoring activities at Solara (August 2007 through July 2008). Developed by Community HousingWorks, a 26-year old non-profit affordable housing developer, Solara is a 56-unit affordable housing complex in the City of Poway in north San Diego County. The units are spread over six separate residential buildings; there is a seventh building that contains the management office, community space, and a computer center.

In addition to significant levels of energy efficiency, each apartment unit has its own solar photovoltaic system. Beyond energy measures, many other green building features were included in the project, including low-water use and edible landscaping, passive and active design to promote healthy indoor air quality, recycled building materials, and ultra low-flow indoor plumbing fixtures. The site is a redevelopment of an urban infill property in close proximity to public transit, shopping, parks, schools and other community services.

Figure 7. Aerial view of the Solara Affordable Housing Apartment Complex in Poway, CA.
Photo Credit: Community HousingWorks, developer/owner of Solara.

The goal of the monitoring activities documented in this report has been to analyze Solara to determine if the energy-related ZENH goals were met with a high statistical confidence level compared to a nearby "baseline" project. The design and modeling projections of Solara have also been compared with actual performance data, along with the impacts the project has had on the local utility system.

Several items of importance are not covered in this report. The fourth ZENH goal of meeting the energy-related targets with a net incremental cost of less than $5,000 per unit was not covered by the post-occupancy monitoring activities and will be addressed comprehensively for both ZENH affordable housing projects in the final report to the Energy Commission due in spring of 2010.

Meanwhile a series of important qualitative features of Solara have not been evaluated. These include the effects the project has had on exposing policy makers to both the potential benefits and the regulatory barriers to implementing high levels of energy efficiency and renewable power generation in an affordable multifamily housing setting. As noted later in this monitoring report, because of regulatory restrictions, the project team often encountered suboptimal choices with regards to basic issues such as utility metering and the structure of the tenant billing regime. While these restrictions may have brought with them a quantitative performance penalty, the project team continued to move forward and spent countless hours working with policy makers to ensure that future projects have better choices. The performance results of the project itself should be evaluated in that context.

As such, Solara's contribution to California's zero net energy future extends beyond the lessons that can be derived from the performance results highlighted in this report. The project was instrumental in focusing policy makers and regulatory agencies on resolving key barriers to the widespread implementation of zero energy affordable housing. In 2009 two of these barriers were removed with the release of the California Utility Allowance Calculator, which allows developers to recoup investments made in energy efficiency and solar photovoltaic infrastructure, and the establishment of Virtual Net Metering tariffs by California investor-owned utilities, which allow developers to significantly reduce costs by installing a single photovoltaic system and apportioning the energy generated to individual units through a simplified billing regime.

2.0 Monitoring Methodology

The project team's approach is to monitor a statistically significant sample of the Solara ZENH units (50%, or 28 units) for a period of one year, while simultaneously monitoring a sample of four conventional units developed and owned by the same developer in 2004 (to serve as a baseline). The baseline units (Hillside) have similar size, age, location, utility providers, and number of occupants, so that the primary differing factors between the baseline and ZENH apartments are the energy efficiency upgrades and use of solar photovoltaics. Specific differentiating factors are discussed further in Section 3. The Hillside units were designed and constructed to be 28% above Title 24 2001 standards, so the comparison of Solara to the baseline units does not represent a comparison with standard code compliant construction. Because the project team monitored only four baseline units, peak demand comparisons may not be statistically valid between Solara and Hillside. However, utility bills were gathered from Hillside (from 25 apartments) to ensure statistical validity of all cost and consumption analyses.

Monitored data for each unit includes utility power consumption and photovoltaic power production. The team also collected electric and gas utility bills from the sites to corroborate the monitored electricity data and to provide overall energy consumption numbers that include natural gas. Unit-specific data including number of bedrooms, area, and location were collected and used for normalizing the data when comparing ZENH units with baseline units.

Data were collected in 15-minute intervals and stored in a standard PC connected to the local network via CAT5 Ethernet cabling. The detailed single line wiring diagram for each apartment building is shown in Figure 2, highlighting the two communications networks used to gather apartment power consumption and PV power production.

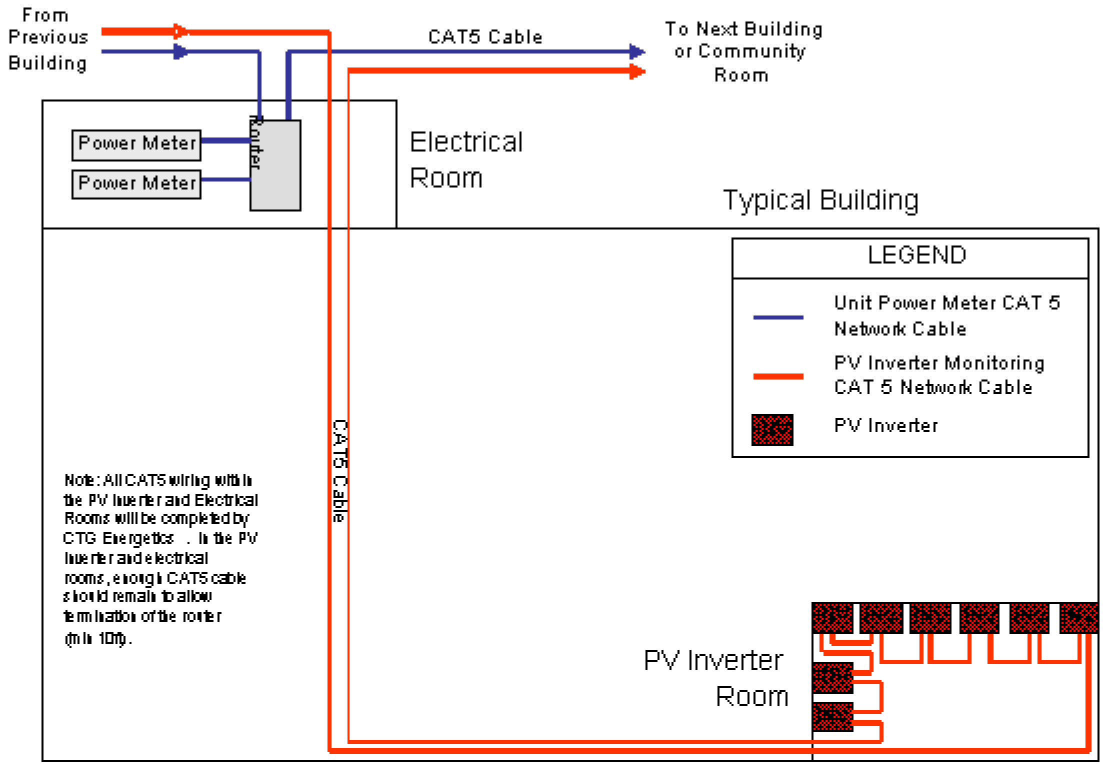

Figure 8. Single Line Diagram of Communications and Power Metering Infrastructure

2.1 Apartment Power Monitoring Equipment

The apartment power meter used on this project was the Dent Instruments ElitePro™ Recording Poly Phase Power meter. The ElitePro™ meter has the capability to monitor 4 current channels and 4 voltage channels (allowing 2 split-phase residential circuits to be monitored simultaneously with one meter), and can record in user-defined intervals ranging from 3 seconds to 24 hours. The meter is small and lightweight (3.2" x 5.9" x 2.4" and 12oz), has a built-in battery with a lifetime of 3 years at 1-minute sampling intervals, and can be purchased with built-in Ethernet connectivity and remote download capability. Please see Appendix D for more information regarding the Dent Instruments ElitePro™ Recording Poly Phase Power meter.

As shown in Figure 8, the Dent power meters were connected to local routers that were in turn connected to a PC located in the Community Room for data archiving. Each Dent power meter was given a unique IP address and the local PC was programmed to call out to the power meters nightly to retrieve the apartment power consumption data.

2.2 Solar Photovoltaic Power Monitoring Equipment

The Solara ZENH project uses Fronius IG inverters to connect the solar PV panels with the apartments and the grid. The inverters have the capacity to monitor and export power production data with the use of an optional data communications card. At the time of the project construction, the data communications cards were not able to be installed by the factory and therefore had to be installed in the field after the inverters were mounted. The cards communicate in a serial ring network as shown in Figure 9 and ultimately connect with a PC for data archiving and display (the same PC used for apartment power consumption archiving). A systems diagram of the Fronius Data Communications network is shown in Figure 9.

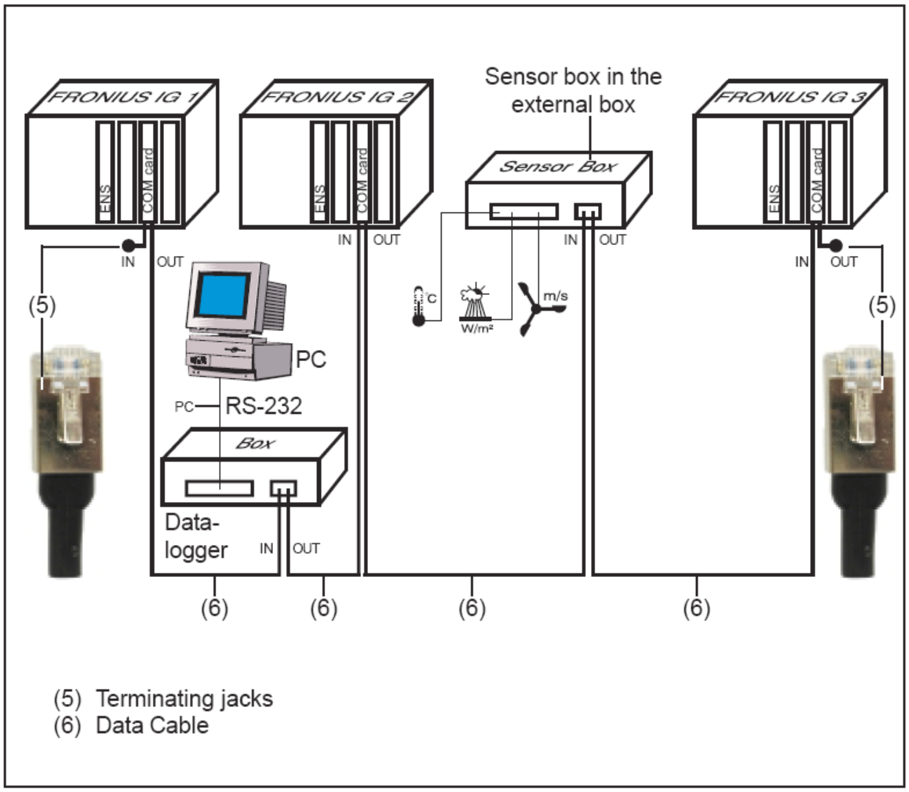

Figure 9. Systems diagram of the Fronius data communications network

2.3 Monitoring Equipment Performance

There were a number of reliability issues with the monitoring equipment and software that caused some amounts of data to be lost during the project. For the monitoring period, approximately 10% of total PV data were lost and 7% of apartment power meter data were lost due to these issues. However, cross-analysis with utility bills and post-processing of the data ensures that there has been no loss of data integrity. A detailed review of the monitoring equipment performance, including start-up and operational issues, can be found in Appendix A.

3.0 Comparison of Solara and Baseline Apartments

3.1 Design and Operational Comparison

Solara and Hillside are located within one mile of each other in Poway, CA. Poway is in California climate zone 10, and is generally hot and dry with significant temperature swings throughout the year. Both projects were constructed by the same developer and have similar income demographics. For more information about the climate of Poway, see Appendix B.

Differences in both the design and operation of the Solara and Hillside communities likely have a significant impact on the energy use comparisons. The three major differences are the following:

1. Differences in utility billing systems. At Solara, energy bills are paid for by the owner and are included in tenant rent, while at the baseline community tenants are billed directly for their actual utility usage.

2. Differences in space heating and domestic hot water systems. At Solara, space heating and domestic hot water are centralized, while at the baseline community each unit has its own space heating and domestic hot water system.

3. Differences in cooking fuel. At Solara, cooking is electric, while at the baseline community cooking is gas.

The reasons Solara includes these unique characteristics is a result of particular regulatory, financial, and design issues faced by affordable multifamily developments. In affordable rental housing, tenants pay no more than 30% of their income for what is called their "housing burden." This housing burden is calculated as rent *plus* utilities. In a situation where tenants pay their own utility bills, the rent received by the owner is reduced by a "utility allowance", which is an estimate of utility costs that will be borne by the tenant. But because this utility allowance is determined by a county-wide survey of existing affordable properties and is not project-specific, developers who invest in energy efficiency and/or renewable energy systems are unable to recoup those investment costs through higher rents. Typically in a new energy efficient project, the tenant receives a standard utility allowance (essentially a reduced rent) as well as the benefits of lower actual utility bills.

At the time of project design in 2004, there was only one practical strategy for the developer of Solara, which needed to borrow money to the finance energy efficiency measures and the photovoltaic systems, to generate a payback from those investments. Utility bills are the responsibility of the owner and the tenants do not receive a utility allowance. Thus, while each unit at Solara has its own electricity meter – as required by law – and own photovoltaic/inverter infrastructure connected to that meter, each meter is in the name of the owner.

This has the practical effect of raising the rent, and thus the cash flow, to Solara without adversely affecting the overall housing cost burden borne by tenants living at the project. While the structural energy efficiency measures plus photovoltaic systems built into the project ensure that this billing structure is financially beneficial to the owner, it does have the practical effect of not providing any pricing signals about energy usage to individual tenants.[1]

Solara uses separate centralized hydronic heating and domestic hot water systems within each of its six residential buildings. Solara's domestic hot water system uses a string of tankless hot water heaters for domestic hot water; the hydronic heating system uses a separate loop with one tankless hot water heater and a 30 gallon storage tank. The decision to centralize these two services was based primarily on the fact that it was a more energy efficient design that cost less money to construct. But in a dense housing situation where space was at a premium and already challenged by the need to accommodate a considerable number of photovoltaic inverters and disconnects, this design also saved a considerable amount of space.

The choice of electricity for cooking fuel followed directly from the decision to centralize space heating and domestic hot water. Once these natural gas-powered functions were centralized, it was deemed an inefficient use of project funds to run gas lines to each individual unit simply to power the cooking stove. Individualized gas lines would have been costly to install and each would have required its own gas meter, along with space necessary to accommodate that meter. The performance implications of cooking energy are detailed in the 4.2 Energy Efficiency Evaluation section of this report.

Both Solara and the baseline project have energy usage associated with common areas – primarily community rooms and light for walkways and surface parking areas – that are linked to house meters separate from individual units. [2] The owner pays the bills for these house meters and because those are ancillary to living areas, their energy use was not monitored.

Table 22 highlights the differences in Solara's design both with respect to 2005 Title 24 and the baseline community, Hillside.

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[1] As of 2009, affordable housing projects in California have an option of determining project specific utility allowances that take into account energy efficiency and/or on-site generation systems. This option was developed by the Energy Commission in part because of the attention that Solara drew to this financial/regulatory obstacle. At Los Vecinos, for example, tenants will be responsible for their own utility bills but the owner of that project is able to recover some of its investment costs through a customized utility allowance.

[2] The circulation pumps for the centralized hydronic heating and domestic hot water at Solara are also connected to the common area meters in each building and therefore are not a significant factor in these comparisons.

Table 22. Differences in the design of Solara with respect to 2005 Title 24 standards and the baseline community, Hillside

Features	Title-24 (2005) Requirements	Solara	Hillside
Attic Insulation	R-30	R-30	R-30
Wall Insulation	R-13	R-13	R-13
Radiant Barrier	No	Yes	No
Insulation Installation Quality Inspection	No	Unofficial	No
Low Air Infiltration Inspection	No	Unofficial	No
Glazing (U-factor and SHGC)	0.41 U-factor 0.41 SHGC	.35 U-factor .35 SHGC Low-E	.35 U-factor .35 SHGC Low-E
Fixed Exterior Shading of Windows	No	Yes	No
Water Heating	Central gas-fired system with 80 % recovery efficiency plus standby losses from storage tank OR Individual tank-type water heaters	Central gas-fired system of multiple tankless hot water heaters with 82% recovery efficiency	Individual gas-fired tankless water heaters
Aquastat[3] recirculation pump	No	Yes	Not Applicable
Space Heating	80% AFUE gas-fired furnace	Central hydronic system with tankless hot water heater and 30 gal storage tank	78% AFUE gas-fired furnace
Air Conditioning efficiency	13.0 SEER	13 SEER with TXV (1 and 2 bedroom units) 14 SEER with TXV (3 bedroom units)	10.1 SEER with TXV
Duct Insulation / Location	R-4.2 for unconditioned spaces	1st floor units have ducts located entirely in conditioned space R-4.2 in unconditioned spaces	R-4.2

[3] An aquastat is a device used to control the heating and pumping of water in hot water systems. Typically an aquastat will enable heating when the water temperature drops below a certain setpoint, and will disable heating when the temperature is above a second setpoint.

Features	Title-24 (2005) Requirements	Solara	Hillside
Tight Duct	Yes (not third party tested)	No (tested)	Not tested
Adequate Airflow Inspection	No	Yes	No
Lighting	2005 Package	All rooms have permanently installed pin-type fluorescent fixtures	Mix of incandescent and florescent (2001 code package)
Appliances	NA	Energy Star Refrigerator and Dishwasher Electric Range and Oven Energy Star Commercial Washers and Gas Dryers located in Community Room	Energy Star Refrigerator and Dishwasher Gas Range and Oven Energy Star Commercial Washers and Gas Dryers located in Community Building
Total PV Installed	NA	141 kW DC (121 kW for units, 20 kW for common areas)	NA
Individual PV System Sizes	NA	2.0 – 2.4 kW/3 bedroom 1.7 – 2.4 kW/2 bedroom 1.7 – 2.4 kW/1 bedroom	NA
2001 T-24 Performance	NA	33%-37% better	28% better
2005 T-24 Performance	Baseline	12%-15% better	Not Applicable

The differences in billing, heating and hot water systems, and cooking fuels have highlighted the difficulties in defining a direct baseline for comparison. In fact, the differences between the two communities have provided insight into design and operation of net zero energy housing. However, because Hillside is less than a mile from Solara, was constructed by the same developer, has the same income demographic, and has similar housing styles and sizes, it is the most appropriate baseline that could be used for the project. The impact of design and operational differences are further explored in the 4.2 Energy Efficiency Evaluation section of this report.

3.2 Normalization and Averaging of Data

Because the baseline apartments (Hillside) are on average 17% larger in square footage and have a higher proportion of 3-bedroom units, comparisons based on energy use data averaged by units tend to favor Solara. Therefore, this report provides ZENH goal performance calculations in three forms: averaged by number of units, normalized by square footage, and/or normalized by number of bedrooms. Because occupancy rates across affordable housing projects are standardized by number of bedrooms, normalizations based on the number of bedrooms can be used as a proxy for occupancy normalizations and are not specifically provided in this report.

In calculating average values, this report focuses solely on total project averages that provide a community-wide characterization of energy usage. For example, the "Average Cost per Bedroom" in a given month is calculated by dividing the total utility costs for that month by the total number of bedrooms. Similarly, the "To-date Average" is the total utility cost to-date divided by the number of bedrooms in the community.

4.0 Results

4.1 Summary Comparison of Project Performance with ZENH Goals

This report analyzes the performance of the Solara community in relation to three of the four California Energy Commission's Zero Energy New Homes (ZENH) program goals: develop housing units that (1) perform 25% better than Title 24 standards, (2) have a 70% reduction in electric utility costs, and (3) have a Summer Peak Demand[4] of 1 kW or less.

In this study, Solara is compared to a baseline community at Hillside, which has no PV generation. At Solara, 28 units were monitored for both electricity consumption and PV generation. Furthermore, the project team obtained utility bill information for each of these units for verification of monitoring accuracy and energy cost information. At Hillside, the team directly monitored four units and obtained utility bills for 25 additional units in the complex.

As shown in Table 23, for the one year monitoring period that ended on August 13, 2008, Solara slightly underperformed with respect to the ZENH cost reduction goal of 70% while significantly out-performing the Summer Peak Demand goal of 1 kW. As Solara was designed to Title 24 2001 standards, the code energy performance goal with respect to 2005 Title 24 was not attained. While Title 24 energy performance cannot be directly compared with monitored data,[5] monitored data are compared with modeled data in a subsequent section of this report.

Table 23. Summary project performance with respect to ZENH program goals

	ZENH Goal	Solara Performance	
		Modeled	Monitored Performance
1. Title 24 Energy Performance Above Code	25%	12-15%[6]	NA
2a. Electricity Cost Reduction (*Per Apartment*)	70%	85%	68%
2b. Electricity Cost Reduction (*Normalized per SF*)			62%
3. Per *Apartment* Summer Peak Demand (kW)	1 kW	NA[7]	-0.17 kW

[4] Summer Peak Demand is defined as average power draw of the project across four hours surrounding the utility's maximum hour power draw. This analysis is to take place for the day with the highest power draw within the hottest month of the year.

[5] Title 24 performance data cannot be directly compared with monitored data because compliance models do not adequately account for loads from plugs, some lighting, and certain other electricity end uses.

[6]. Range depends on building/unit type and orientation.

[7] Summer peak demand performance cannot be evaluated for modeled performance due to lack of consistency between utility peak timing and weather data in the simulation environment. That is, energy modeling is based on standard, prescribed temperature values, whereas utility peak timing is influenced significantly by actual local weather conditions. Modeling data did show that it was highly likely that enough PV was installed to lower peak demand below the ZENH threshold.

4.2 Energy Efficiency Evaluation

Solara was originally designed to exceed Title 24 2001 standards by nearly 40%. Preliminary projections show that when compared with new 2005 standards the project is approximately 15% above code, depending on building orientation and unit type. Actual performance with respect to Title 24 can be inferred through comparison with modeled data. However, many of the energy end use components of actual buildings are not captured with Title 24 residential compliance modeling (e.g., lights, plug loads, and appliances), complicating direct comparisons with energy model performance predictions.

Extensive energy modeling was undertaken to optimize energy efficiency measures included in the project and to provide a means to estimate energy/cost performance and inform PV system sizing. Solar production was modeled using the online estimating program PV Watts[8] to determine annual electricity output in kilowatt-hours (kWh). Title 24 compliance models were developed using EnergyPro Version 3. However, as described above, additional calculations outside of the energy modeling software were necessary to include lighting, appliance, and plug load consumption in order to provide more accurate energy consumption projections, particularly for PV system sizing. EnergyPro Title 24 projections for cooling energy use were also modified due to factors not accounted for in EnergyPro low-rise residential load calculations, such as plug and lighting loads that generate heat. Overall, the project team needed to perform a significant amount of post-processing of Title 24 performance results to create projections of actual energy use for the Solara apartments. To reduce the cost and effort in designing Zero Net Energy Housing, future improvements to the residential Title 24 modeling rule set should include consideration of all site energy uses.

The comparison of modeled performance to observed performance for the entire year of monitoring data (Aug 2007 – Jul 2008) is shown in Table 24. The data suggest good comparison between observed and modeled projections for gross energy consumption, with only a 2% difference. However, PV production is 9% higher than projected for the year. This could be due to a number of factors, such as seasonal weather variations, de-rating factors used to account for annual degradation of solar panel performance over time, and/or more efficient solar panels or inverters than projected.

Because PV production was above projections, net electricity consumption was significantly lower than modeled predictions. Had PV production been similar in the modeled and observed cases, net electricity consumption would be nearly identical in the modeled and observed results. Even though net electricity consumption is significantly lower than the modeled projections, net electricity cost is only slightly lower. This difference is mainly due to the fixed $0.17 minimum daily fee charged by the utility for grid interconnection. Account holders must pay this fee regardless of actual net electricity consumption during that month.

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[8] Although the Energy Commission's own New Solar Homes PV calculator is more exact than PV Watts, it was not available until after the Solara project was completed.

Table 24. Comparison of apartment average modeled and observed data at Solara for the one year monitoring period ending in August of 2008

Category	Modeled	Observed	Variation in Observed Performance vs. Modeled
Gross Electricity Consumption (kWh/apartment)	3612.4	3709.6	3%
PV Production (kWh/apartment)	2936.5	3228.9	10%
Electricity Cost ($/apartment)	$132.20	$125.55	5%
Natural Gas Consumption (therms/apt)[9]	80.0	211.9	165%

Natural gas consumption was significantly higher than predicted from the energy models. This could be due to a number of factors including space heating system design that requires the hydronic hot water loop to be active year round; deviations from hot water consumption assumptions in the Title 24 energy modeling rule set; and potentially inaccurate heating assumptions in the Title 24 energy modeling rule set for hydronic heating applications.[10] It is difficult to pinpoint the exact reason for the extremely high natural gas consumption when compared to modeled data because of the lack of end-use or apartment-level consumption data for domestic hot water and space heating use.

When considering modeled and observed performance for electricity, it is important to understand the projected reductions for each fuel type modeled, not simply overall Title 24 performance. At Solara, the majority of the performance above code in the modeling exercise resulted from energy efficiency measures targeted at reducing heating and domestic hot water (natural gas) fuel use. When only those measures targeted at electricity consumption are considered (in this case, reducing cooling energy use), Solara would be expected to use 8.5% less electricity than the baseline community.

However, for the monitoring period, Solara gross electricity consumption was approximately 16% higher than the baseline community when normalized for square footage. Potential explanations for this phenomenon include these: (1) the behavioral effect of different billing methodologies, whereby Solara residents do not pay directly for their utilities and the baseline residents do, and (2) differences in the type of fuel used for cooking, whereby Solara uses electricity and Hillside uses natural gas. In order to explore this phenomenon in more detail, the project team conducted further analysis to analyze the impact of electric cooking appliances at Solara and their potential impact on energy performance compared with the baseline community.

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[9] Observed data were projected to annual figures as only 7 months of natural gas consumption were available for Solara.

[10] However, the unusual nature of the hydronic heating system design at Solara likely impacts T24 modeling assumptions, resulting in inaccurate gas consumption predictions.

Specifically, to better compare the two communities, Solara's gross electricity consumption could be adjusted to exclude energy use associated with electric cooking. Based on the most efficient of conventional appliances at the time, the impact of the electric ovens and ranges at Solara was estimated to be 440 kWh/yr per apartment.[11]

Tables 5 to 7 show that the projected electricity use for cooking has a significant impact on the electricity performance comparison between the two communities. "Observed Data" in the tables below refer to the actual electricity consumption of the apartments without adjustment to remove the electricity load from the cooking appliances. Without adjustment, Solara and Hillside consume nearly the same amount of electricity on a per apartment basis, but Solara uses approximately 12% more electricity when normalized for square footage. With the estimated electricity for cooking removed, Solara improves to 11% better than Hillside on a per apartment basis and nearly identical performance when normalized for square footage. This result suggests that even if the two communities used the same primary fuel for cooking, the energy efficiency measures at Solara *would not* have resulted in significant reduced electricity consumption. However, this may be attributed to differences in the billing structures whereby Solara residents do not pay for their own utility bills and Hillside residents do pay their own bills.

Table 25. Comparison of gross electricity consumption (excluding PV), including Solara consumption adjusted to exclude electricity use for cooking

	Gross Electricity Consumption (kWh)		Reduction from Baseline
	Solara	Baseline (Hillside)	
Observed Data – per apartment	3709.6	3693.7	0%
Observed Data – per 1000 SF	4097.1	3655.4	-12%
Adjusted to Remove Cooking Electricity – per apartment	3269.6	3693.7	11%
Adjusted to Remove Cooking Electricity – per 1000 SF	3645.0	3655.4	0%

As shown in Table 26, when PV production is included, performance of Solara versus the baseline community improves from an 87% to a 99% normalized reduction with the electricity use for cooking removed. Based on these data, had Solara used gas cooking appliances, the community would have consumed nearly zero electricity on net for the year.

Table 26. Comparison of net electricity consumption (including PV) including Solara consumption adjusted to exclude electricity use for cooking

	Net Electricity Consumption (kWh)		Reduction from Baseline
	Solara	Baseline (Hillside)	

[11] Assumes the use of the most efficient ovens and ranges available at the time of analysis, consuming 220kWh per appliance per year, http://oee.nrcan.gc.ca/energystar/english/consumers/products.cfm?PrintView=N&Text=N

Observed Data – per apartment	480.7	3693.7	87%
Observed Data – per 1000 SF	477.7	3655.4	87%
Adjusted to Remove Cooking Electricity – per apartment	40.7	3693.7	99%
Adjusted to Remove Cooking Electricity – per 1000 SF	45.4	3655.4	99%

The electric cooking appliances at Solara have a significant impact on electricity costs compared with the baseline community. The data in Table 27 show that, using the estimated cooking appliance consumption, the adjusted total electricity costs for the monitoring period are 82-84% below the baseline, well above the cost reductions with the unadjusted data (62-68% reduction). With this adjustment, the electricity cost performance exceeds the Energy Commission's ZENH program goal of at least a 70% reduction. This suggests that if the same cooking fuel had been used in both Solara and the baseline community, the ZENH electric cost reduction goal would have been met by the project.

Table 27. Comparison of electricity cost including Solara consumption adjusted to exclude electricity use for cooking

	Net Electricity Cost (total $)		Reduction from Baseline
	Solara	Baseline (Hillside)	
Observed Data – per apartment	$125.55	$390.70	68%
Observed Data – per 1000 SF	$145.03	$383.77	62%
Adjusted to Remove Cooking Electricity – per apartment	$62.05[12]	$397.40	84%
Adjusted to Remove Cooking Electricity – per 1000 SF	$69.18	$383.77	82%

[12] Because the net adjusted electricity use is nearly zero for the year (see Table 26), this represents the minimum daily billing charge from SDG&E.

4.3 Energy Cost and Usage Evaluation

4.3.1 Electricity

When compared to the baseline apartments, as in Table 28 and

Table 29, net electricity costs and consumption for the Solara apartments are significantly reduced for the year. Note that the reduction in cost is less prominent when normalized by square foot or bedroom. The gross usage and cost indicate that the electricity usage at Solara is significantly higher than Hillside when PV production is not considered (as discussed in the Energy Efficiency Evaluation section).

Table 28. Comparison of annual electricity costs

	Solara		Hillside (Baseline)	Reduction from Baseline	
	Net (With PV)	**Gross (Without PV)**	**Gross (Without PV)**	**Net (With PV)**	**Gross (Without PV)**
Average Utility Cost – *per Apartment*	$125.55	$546.56	$390.70	68%	-40%
Average ECI[13] – *per 1000 SF*	$145.03	$631.39	$383.77	62%	-65%
Average ECI – *per BR*	$59.58	$259.38	$151.94	61%	-71%

Table 29: Comparison of annual net and gross total electricity consumption (kWh)

	Solara		Hillside (Baseline)	Reduction from Baseline	
	Net (With PV)	**Gross (Without PV)**	**Gross (Without PV)**	**Net (With PV)**	**Gross (Without PV)**
Average Consumption - per Unit	480.7	3709.6	3693.7	87%	0%
Average EUI[14] - per 1000 SF	477.7	4097.1	3655.4	87%	-12%
Average EUI - per BR	228.1	1760.5	1458.0	84%	-21%

[13] Electricity Cost Intensity – a measure of normalized electricity cost per square foot or per bedroom.

[14] Energy Use Intensity - measure of normalized electricity consumption per square foot or per bedroom.

A breakdown of all units' annual net energy consumption is shown in Figure 10 for comparison. For the year, ten Solara units are net exporters to the grid, and on average PV production covers over 90% of the total electricity consumption of the units, as shown in

Table 30.

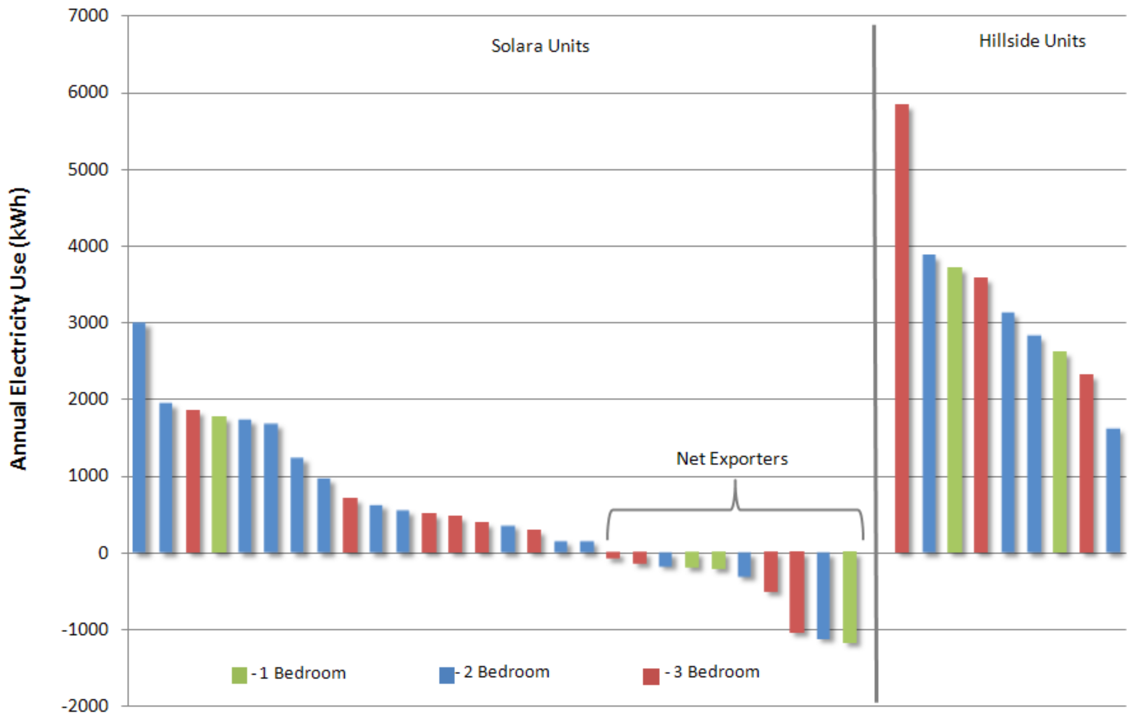

Figure 10. Net annual energy consumption for Solara (PV included) and Hillside units[15]

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[15] Electricity usage at Hillside presented in Figure 10 is based on utility bill data. For comparison purposes, the presented ratio of apartment sizes, by bedroom, at Hillside match the size ratio of monitored apartments at Solara. Within each apartment size group, a representative sample of maximum, minimum and mean consumers of electricity is presented for Hillside.

Table 30 shows the performance of each individual apartment monitored during the project. While in general the PV system size follows the number of bedrooms (that is, the largest PV systems are on 3 bedroom units and the smallest are on 1 bedroom units), there are inconsistencies with PV system size per apartment due to space constraints of the roof and carports. For example, apartment 611 has only one bedroom, but incorporates the largest PV system.

Table 30. PV production as a percentage of total electricity consumption at Solara

Solara Apartment Number	Area (sq.ft.)	Number of Bedrooms	PV System Size (W)	Annual Data: Net Electricity Consumption (kWh)	Annual Data: PV Production (kWh)	Annual Data: Gross Electricity Consumption (kWh)	Annual Data: PV Production as % of Total Consumption
211	1026	3	2380	392.5	3538.5	3930.9	90%
215	1026	3	2380	497.4	3532.0	4029.3	88%
221	1026	3	2380	468.3	3403.7	3872.0	88%
225	1026	3	2380	-506.0	3294.2	2788.2	118%
501	1026	3	2380	294.3	3654.7	3949.0	93%
505	1026	3	2380	1853.1	3710.4	5563.5	67%
531	1026	3	2380	-1033.9	3040.1	2006.2	152%
535	1026	3	2380	-143.6	3294.4	3150.8	105%
631	1019	3	2380	695.6	2949.2	3644.8	81%
201	894	3	2040	-98.9	3153.9	3055.0	103%
205	894	2	2040	451.9	3200.2	3652.1	88%
231	894	2	1700	325.1	2684.9	3010.0	89%
235	894	2	2040	1823.8	3852.3	5676.0	68%
511	883	2	2040	1985.4	2611.4	4596.8	57%
515	883	2	2040	3132.1	3033.6	6165.7	49%
521	883	2	2040	1913.3	2546.8	4460.1	57%
525	883	2	2040	1245.9	3077.9	4323.8	71%
601	883	2	2380	-1339.5	3694.8	2355.4	157%
605	883	2	2380	1169.0	3587.2	4756.2	75%
621	865	2	2380	-601.3	3499.5	2898.1	121%
625	865	2	2040	674.5	3641.9	4316.4	84%
635	888	2	2040	-400.0	3059.4	2659.4	115%
651	883	2	2380	186.2	3316.8	3503.0	95%
655	883	2	2380	280.2	2843.1	3123.4	91%
611	659	1	2380	-1175.1	3604.9	2429.8	148%
615	659	1	1700	2029.2	2528.1	4557.4	55%
641	659	1	2040	-447.3	2704.3	2257.0	120%
645	659	1	1700	-212.6	3352.3	3139.8	107%
Average	897	2.2	2186	480.7	3228.9	3709.6	94%

Table 10 shows the performance of each individual apartment monitored during the project. While in general the PV system size follows the number of bedrooms (that is, the largest PV systems are on 3 bedroom units and the smallest are on 1 bedroom units), there are inconsistencies with PV system size per apartment due to space constraints of the roof and carports. For example, apartment 611 has only one bedroom, but incorporates the largest PV system.

As shown in the consumption of each unit varies widely. Specifically, the coefficient of variation[16] of gross consumption (kWh) is 0.29, double that of PV production (kWh per kW DC installed) which has a coefficient of variation of 0.12. Furthermore, the individual gross consumption per bedroom ranges anywhere from 668.7 kWh to 4557.4 kWh, which represents almost an order of magnitude variation. This suggests that individual occupant behavior has a significant impact on energy use and cost in zero energy home units.

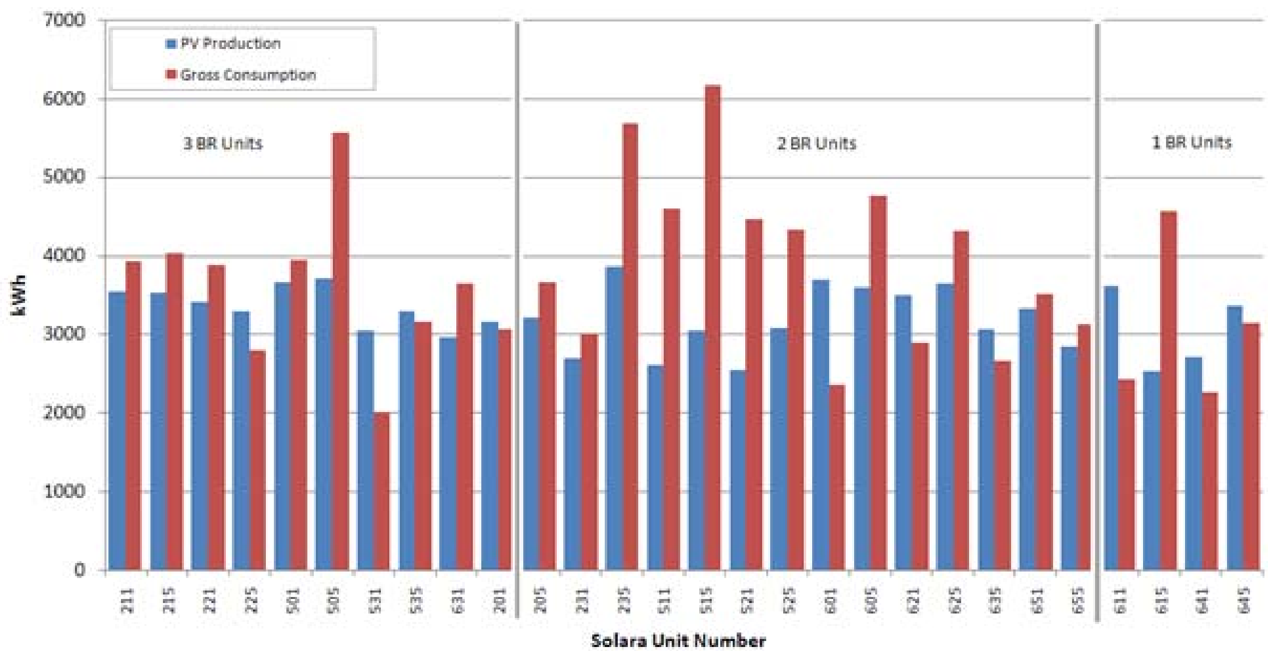

Figure 11. Annual PV production and gross electricity consumption for monitored Solara units

4.3.2 Natural Gas

Natural gas consumption data were not available from Solara before January of 2008; therefore, only seven months of data are available for comparison with the baseline community. At Solara, natural gas is used for central domestic water heating and central hydronic space heating. At Hillside, gas is used for cooking, and individual tankless water heaters and forced hot air space heating. As shown in Table 31, total average annual natural gas usage at Solara is slightly higher than at Hillside.

However, because Solara uses electric cooking appliances, gas consumption at Solara would be even higher than shown in Table 31 if adjusted to include gas use for cooking (in order to directly compare gas consumption with Hillside, which uses gas for cooking). Based on research from the National Renewable Energy Laboratory and published in the Building America Research Definition Benchmark (2009), if Solara used natural gas appliances, it would

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[16] Coefficient of variation (CV) is a dimensionless measure of the dispersion associated with a set of data. This metric is defined as the standard deviation of the data set divided by the mean of the data set. Therefore, a data set with a larger amount of dispersion is characterized by a higher CV.

be expected to consume an additional 39 therms per year per unit, or an additional 3.25 therms per month per unit. Adjusting for the difference in cooking fuels, Solara would then be expected to use 18% more natural gas than Hillside (see Table 32), suggesting that the energy measures that target natural gas at Solara were not effective. This result can be attributed to a number of factors, such as the differences in billing structures (Hillside residents pay for their natural gas use directly and Solara residents do not), the use of tankless hot water heaters at Hillside for domestic hot water vs. the unique central domestic water heating system at Solara, and/or the design and controls of the centralized hydronic heating systems at Solara (discussed in more detail below).

Table 31. Natural gas usage and cost comparison, including all sources of natural gas consumption

Month	Natural Gas Usage (Therms per 1000 SF)			Natural Gas Cost ($ per 1000 SF)		
	Solara	Hillside	Reduction	Solara	Hillside	Reduction
Jan	25	38.9	36%	$39	$42	7%
Feb	27.1	29.2	7%	$42	$30	-42%
Mar	20.8	20.4	-2%	$35	$22	-56%
Apr	18.9	15.2	-25%	$34	$18	-87%
May	17.4	12.8	-36%	$33	$18	-78%
Jun	15.4	9.7	-59%	$30	$14	-120%
Jul	13.1	9.3	-40%	$24	$13	-91%
Total	137.8	135.5	-2%	$237	$157	-51%

Table 32. Natural gas usage comparison, adjusted for differences in cooking fuels

Month	Natural Gas Usage (Therms per 1000 SF)		
	Solara – Adjusted	Hillside	Reduction
Jan	28.2	38.9	28%
Feb	30.3	29.2	-4%
Mar	24	20.4	-18%
Apr	22.1	15.2	-45%
May	20.6	12.8	-61%
Jun	18.6	9.7	-92%
Jul	16.3	9.3	-75%
Total	160.2	135.5	-18%

Examining the monthly gas consumption patterns, higher natural gas usage at Solara is more predominant during the summer months due to the design and year-round operation of the central hydronic heating system. Observed gas consumption is lower during January at Solara, even when adjusted for differences in cooking appliances, suggesting that the Solara centralized hydronic and domestic hot water systems may be more efficient during the coldest winter months. However, more data are needed to draw a meaningful conclusion.

As shown by the data above, Solara consumes more natural gas during the non-heating shoulder and summer months due to system losses from the continuously running and circulating heating system. This design flaw was discovered by the project team after the HVAC systems were installed and the walls were closed up. Thus a correction was deemed too costly to implement. Now that there is data showing how much this issue is costing the project in operating costs, an analysis is being undertaken to determine if a retrofit makes financial sense. As described above, more data are needed to understand the efficiency of the centralized hydronic heating and domestic hot water systems during the winter months. However, based on the performance during the non-heating season, it is clear that future projects that use centralized hydronic heating systems should include demand-based controls, in order to avoid continuously operating heating loops in the absence of heating demand from the residents. Demand based controls for centralized multifamily heating systems may also be an important topic for future Title 24 Codes and Standards Enhancement (CASE) study research.

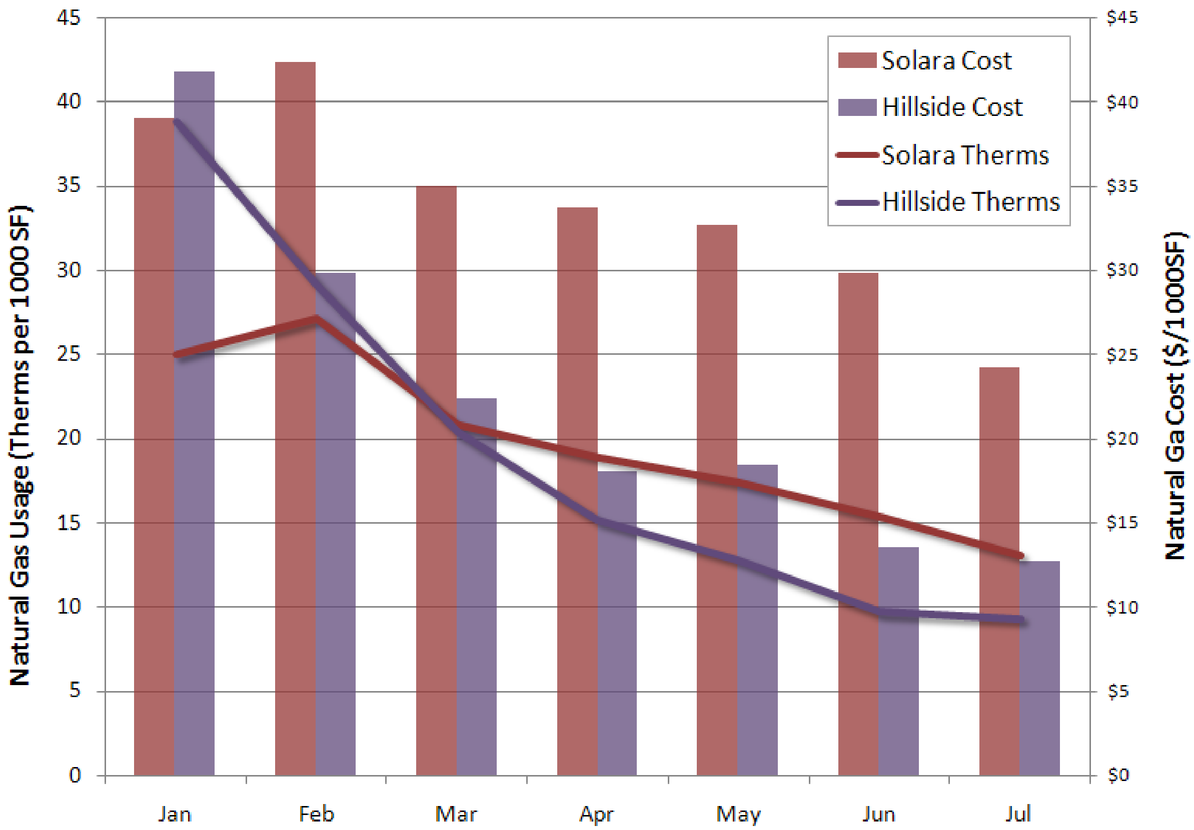


Figure 12. Monthly natural gas consumption and cost comparison for 2008

Natural gas cost is significantly higher at Solara when compared to Hillside for two reasons: (1) slightly higher usage, and (2) use of different rate structures. Solara is not on the low income rate structure (GRLI) while Hillside is. Also, Solara is incorrectly on a single family residential rate (GR), even though multiple apartments in each building are on centralized gas meters. This results in artificially low baseline allowances (because the single family rate structure assumes only one dwelling per meter) and an inflation of non-baseline charges. As shown in Table 31, even though Solara used only 2% more natural gas than Hillside for the seven months that ended in July 2008, Solara paid 51% more due to the differences in rate structures between the two communities (discussed in further detail below).

4.3.3 Total Site Energy

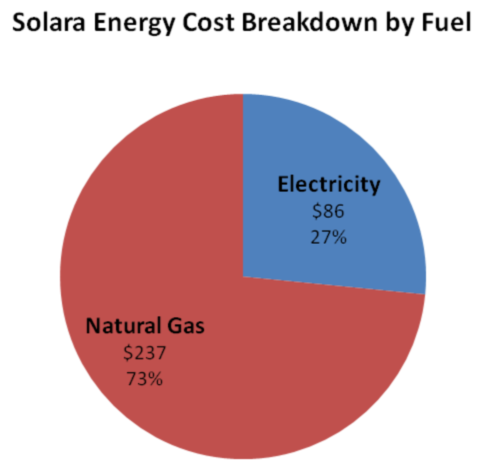
The project team analyzed total site energy for the combined performance of electricity and natural gas between Solara and Hillside. Site energy consumption considers only the direct consumption of fuels on the project site and does not consider primary fuel consumption or losses associated with electric power production, transmission, or natural gas distribution. However, site energy consumption provides a straightforward mechanism for comparing the energy efficiency and utility cost between the two communities.

As shown in Table 33, for the first seven months of 2008, the increased gas use and reduced electricity use at Solara result in a 31% net reduction in total site energy consumption. On a gross consumption basis (without PV power), Solara uses approximately 10% more total site energy. Total energy costs are reduced by approximately 14% when compared with Hillside; had the correct natural gas billing structure been used at Solara, however, the total cost reduction from baseline would be much higher, as discussed in Section 0.

Table 33. Total site energy use intensity (EUI) and energy cost intensity (ECI) comparison between Solara and Hillside for the first seven months of 2008

Month	Total EUI (kBtu per 1000 SF)					Total Average ECI ($ per 1000 SF)		
	Solara Net	Solara Gross	Hillside	Net Reduction	Gross Reduction	Solara Net	Hillside	Reduction
Jan	2843.3	3477.9	4956.7	43%	30%	$53.3	$75.4	29%
Feb	2839.6	3761.4	3795.0	25%	1%	$55.2	$56.6	3%
Mar	1934.3	3148.5	2772.4	30%	-14%	$43.9	$45.0	2%
Apr	1713.1	2987.8	2348.1	27%	-27%	$42.6	$43.7	3%
May	1520.8	2922.8	2159.4	30%	-35%	$41.1	$45.3	9%
Jun	1639.6	3136.2	1899.5	14%	-65%	$44.3	$52.9	16%
Jul	1498.4	2905.2	2335.4	36%	-24%	$42.1	$57.8	27%
Total	13989.2	22339.7	20266.6	31%	-10%	$322.4	$376.9	14%

The relative normalized consumption by fuel type for each community is shown in Figure 13 for the first seven months of 2008. Whereas natural gas costs comprise only 41% at Hillside, natural gas costs are more than 70% of the total utility expenditure at Solara. This result is due to both the fact that Solara's electricity consumption is much lower than the baseline community's and the use of the incorrect billing structure at Solara, which greatly inflates the cost of natural gas.



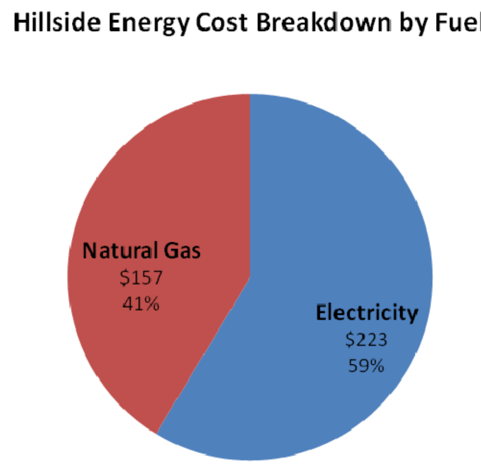


Figure 13. Comparison of net normalized energy cost ($/1000SF) by fuel for Solara and Hillside for the first seven months of 2008

The monthly trends in total energy costs and consumption for both Solara and the baseline community are shown in **Error! Reference source not found.**. During the winter months, total gross site energy consumption (without PV) at Solara is below the baseline community, although this trend reverses in the spring and summer months. Total net site energy consumption remains lower than the baseline community even though gross consumption does not decrease as seen with Hillside; this is due to increasing solar availability and production from the PV panels at Solara.

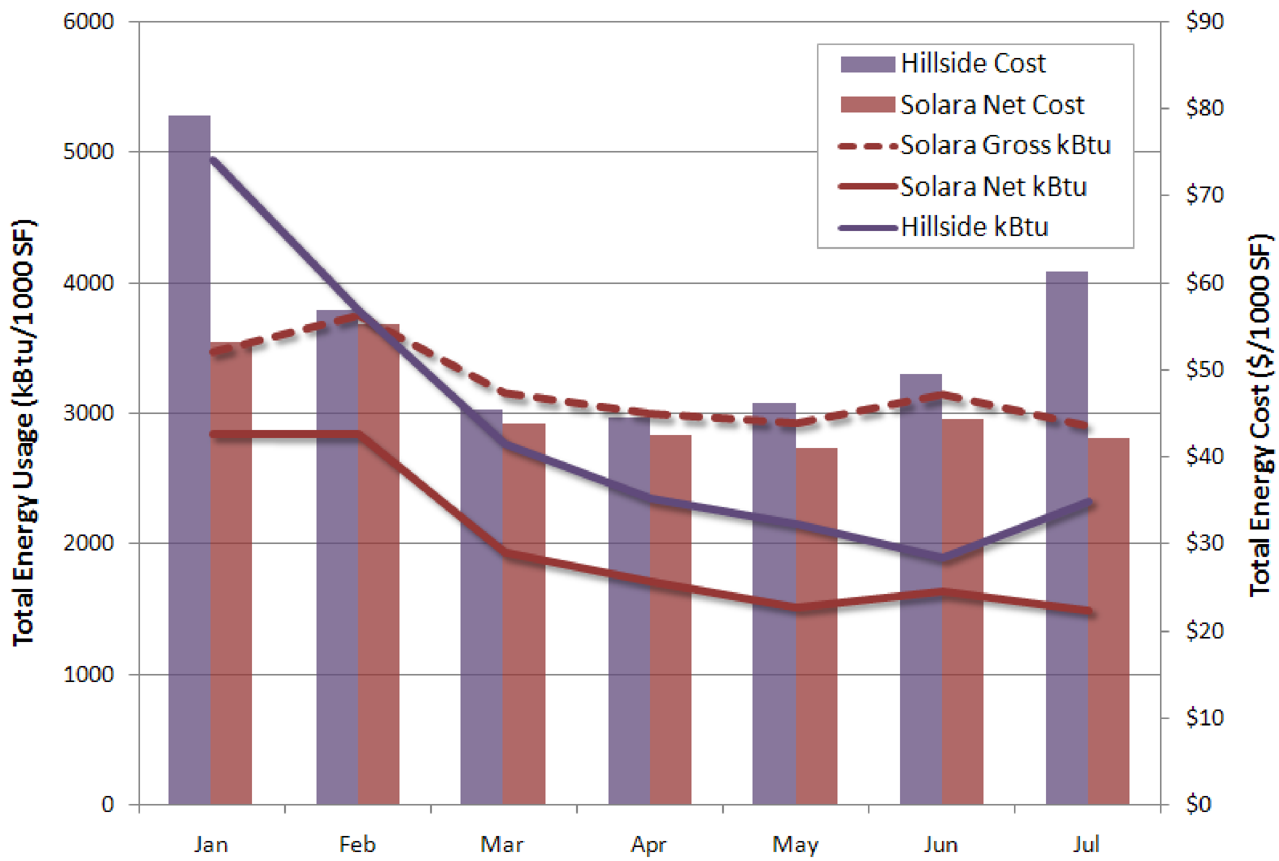


Figure 14. Monthly comparison of site energy costs and consumption for 2008

4.3.4 Utility Rate Analysis

4.3.4.1 Gas Utility Rate and Schedule

As discussed earlier, due to regulatory and financial constraints on multifamily affordable housing developments, the owner pays the utility bills at Solara. Thus the project is not eligible for low-income household utility discounts which have significant impacts on the cost of natural gas when compared with the baseline community (see Table 34). For the months when data were available, natural gas costs were 30% higher on average at Solara than Hillside. Although both communities are on residential natural gas service rates (SDGE Schedule GR), Hillside residents qualify for a 20% discount on all customer, commodity, and transportation charges through the California Alternate Rates for Energy (CARE) program. This program provides utility bill discounts for low income households, and although Solara residents may meet the low income requirements, the Solara community cannot apply for the program because individual tenants do not pay bills. Not only does the Hillside community receive a 20% energy discount, but these tenants also pay a reduced Public Purpose Program Surcharge that adds another 1.5% discount under CARE. Therefore, the total low-income discount is approximately 21.5%, none of which Solara is accessing due to its utility payment methods.

Table 34. Cost of natural gas ($/therm) at Solara and Hillside communities

Month	**Natural Gas Cost ($/therm)**

	Solara	Hillside	Reduction
Jan	$1.56	$1.07	-45%
Feb	$1.56	$1.02	-53%
Mar	$1.68	$1.10	-53%
Apr	$1.78	$1.19	-50%
May	$1.87	$1.44	-31%
Jun	$1.93	$1.40	-38%
Jul	$1.85	$1.36	-36%
Average	$1.75	$1.22	-43%

Solara was placed on an inappropriate natural gas billing rate schedule (Schedule GR) which further explains the cost increase at Solara. Both communities are billed on the same schedule, which is meant for *individually* metered residential customers. Although this schedule is appropriate for Hillside, natural gas usage from the central water heaters is metered by building at Solara, not by individual units. Therefore, even though up to 12 units share one meter at Solara, the baseline allowance for each account is based only on a single unit. As a result, the majority of Solara's gas usage is charged at higher non-baseline rates, which are approximately 43% higher than baseline charges.

Instead of continuing with the single-family gas rate (Schedule GR), Solara could significantly reduce gas costs by using the San Diego Gas and Electric (SDG&E) multi-family rate (Schedule GM). Unlike Schedule GR, Schedule GM calculates baseline allowance based on the number of units on each gas meter. Based on each schedule's baseline allowances, savings in service charge for Buildings D and G at Solara have been calculated in Table 35 and Table 36. Note that these costs do not include state regulatory fees, Public Purpose Program fees, or energy charges, all of which are independent of baseline allowances. Detailed estimates of natural gas cost savings for both 8-and 12-unit buildings are shown in Table 35 and Table 36. Based on preliminary calculations that suggest approximately $4 savings per month, per unit, switching to Schedule GM could save the Solara community a total of $2,700 in annual gas costs.

Table 35. Energy charge savings for Building D (12 apartments)

Month	Schedule GM Service Charges		Schedule GR Service Charges		Savings	
	Baseline	Non-Baseline	Baseline	Non-Baseline		
Jul	$64	$5	$8	$88	$27	28%
Jun	$70	$15	$8	$107	$29	26%
May	$96	$0	$16	$117	$38	28%
Apr	$98	$0	$24	$110	$35	26%
Mar	$105	$0	$24	$120	$39	27%
Feb	$134	$0	$27	$157	$51	27%
Jan	$133	$0	$24	$161	$52	28%
Dec	$130	$0	$27	$152	$49	27%
Total	$851		$1,169		$319	27%

Table 36. Building G (8 apartments)

Month	Schedule GM Service Charges		Schedule GR Service Charges		Total Savings	
	Baseline	Non-Baseline	Baseline	Non-Baseline		
Jul	$42	$26	$8	$77	$17	19%
Jun	$47	$32	$8	$89	$18	19%
May	$79	$0	$16	$93	$30	27%
Apr	$80	$0	$24	$83	$27	25%
Mar	$86	$0	$24	$92	$29	26%
Feb	$115	$0	$27	$130	$42	27%
Jan	$114	$0	$24	$132	$43	27%
Dec	$123	$0	$27	$141	$45	27%
Total	$744		$994		$250	25%

4.3.4.2 Electricity Rate and Schedule

As was the case with natural gas, Solara does not qualify for CARE discounts on electricity rates because tenants do not pay their own bills. If this 20% discount were applied to Solara, the electricity cost reduction per square foot would be 82% and greatly exceed the 70% ZENH goal.

Furthermore, the utility's minimum bill charge ($0.17 per day or $62.05 per year) adds measurable costs to Solara's electricity bills. Even though some apartments at Solara are net exporters to the grid, they are still charged $62.05 per year to stay connected to the grid through minimum daily charges. SDG&E gives credit on an annual basis if the PV system generated more electricity than the customer used, but this generation credit cannot be used to pay down the minimum bill charge (nor will customers be reimbursed for their excess generation). As shown in Table 37, the total net annual cost to the monitored Solara units is approximately $3,515, but if the annual generation credit were applied to the minimum charges, the total net annual cost would be reduced by an estimated $526, or 15%. The impact of the minimum charge is especially significant due to the generally low net electricity usage at Solara. In fact, if excess generation credit could be applied to minimum charges, five Solara units would have no electricity costs at all, and an additional two units would be billed under $5 for the year.

During the monitoring period, payments for PV generation in excess of 100% of gross electricity consumption was not allowed by California law. In 2009, AB 920 (Huffman) was signed into law directing California utilities to begin to pay net metering customers for such excess generation beginning in 2011. The amount per kWh that will be paid to customers with excess generation and in what form that payment will take, is still under negotiation between the California Public Utilities Commission and California electricity providers. Until this rate and form of payment is determined, it is not possible to analyze what effect this new legislation will have on Solara customers who conserve electricity and therefore are net electricity generators. However, the excess amount of electricity that will have to be generated in order to offset the minimum charge and achieve a true zero electricity bill is significant.

Table 37. Annual electricity cost at Solara with and without annual generation credit being used to pay down minimum bill charges

Cost Category	Annual Electricity Cost		Cost Reduction
	Current Practice	With Generation Credit Applied to Minimum Charges	
Total	$3,515	$2,989	15%
per kWh	$0.26	$0.22	
per unit	$125.55	$106.74	
per 1000 SF	$145.03	$123.31	
per Bedroom	$59.58	$50.66	

Note: Data for only the 28 monitored units have been included.

4.4 Peak Electrical Demand Evaluation

4.4.1 ZENH Summer Peak Demand Performance

The ZENH program established that projects should to have an average summer peak demand of less than 1 kW per apartment. The summer peak demand is defined as the per apartment power draw averaged over the two hours before and two hours after the moment of utility's maximum power draw during the hottest month of the year.

For the annual monitoring period, August 2007 is the hottest month (i.e. highest average temperature), and the highest power draw occurred on September 3rd, Labor Day. The highest power draw on this day, however, occurs at 12:00 pm, much earlier in the day than is typically observed. This unusual peak timing is likely due to customers staying home and using air conditioning during the holiday. Utilizing this atypical peak day to assess Solara's demand performance, therefore, would be inappropriate. Instead, August 30th was selected because it was the hottest day of the hottest week in the hottest month (August).

As reported by SDG&E, the highest power draw on August 30th occurred at 2:00 PM. Therefore, as seen in Figure 15, calculation of Solara's summer peak demand spans 12:00 PM to 4:00 PM and results in a value of -0.17 kW per apartment. This negative value is well below the ZENH goal of 1 kW per apartment and also indicates that Solara apartments were exporting energy back to the grid at the time the system was most stressed.

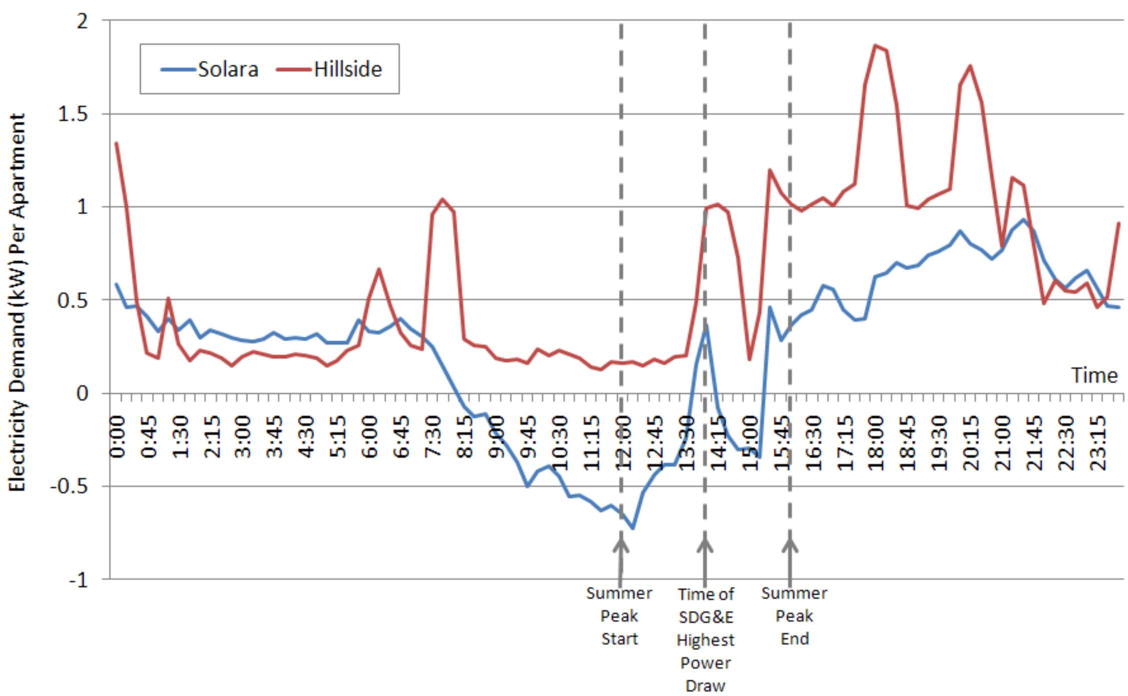


Figure 15. Electricity demand per apartment of Solara and Hillside communities on the day of the annual SDG&E summer demand peak: August 30th, 2007

4.4.2 Monthly Peak Demand

Comparing demand of the communities at the time of the monthly demand peaks provides valuable insight into demand performance throughout the year. For this purpose, monthly demand peak is defined as the time during each SDG&E billing month when the system demand is at its highest (i.e. most stressed). The demand per apartment at both communities can then be determined at these monthly peak demand times for each grid.

As shown in **Error! Reference source not found.**, Solara is a net exporter of electricity at the time of the monthly demand peaks for nine months out of the year. Furthermore, the highest average demand at Solara during SDG&E's monthly demand peaks is just over 0.5 kW, compared with 1.3 kW at Hillside.

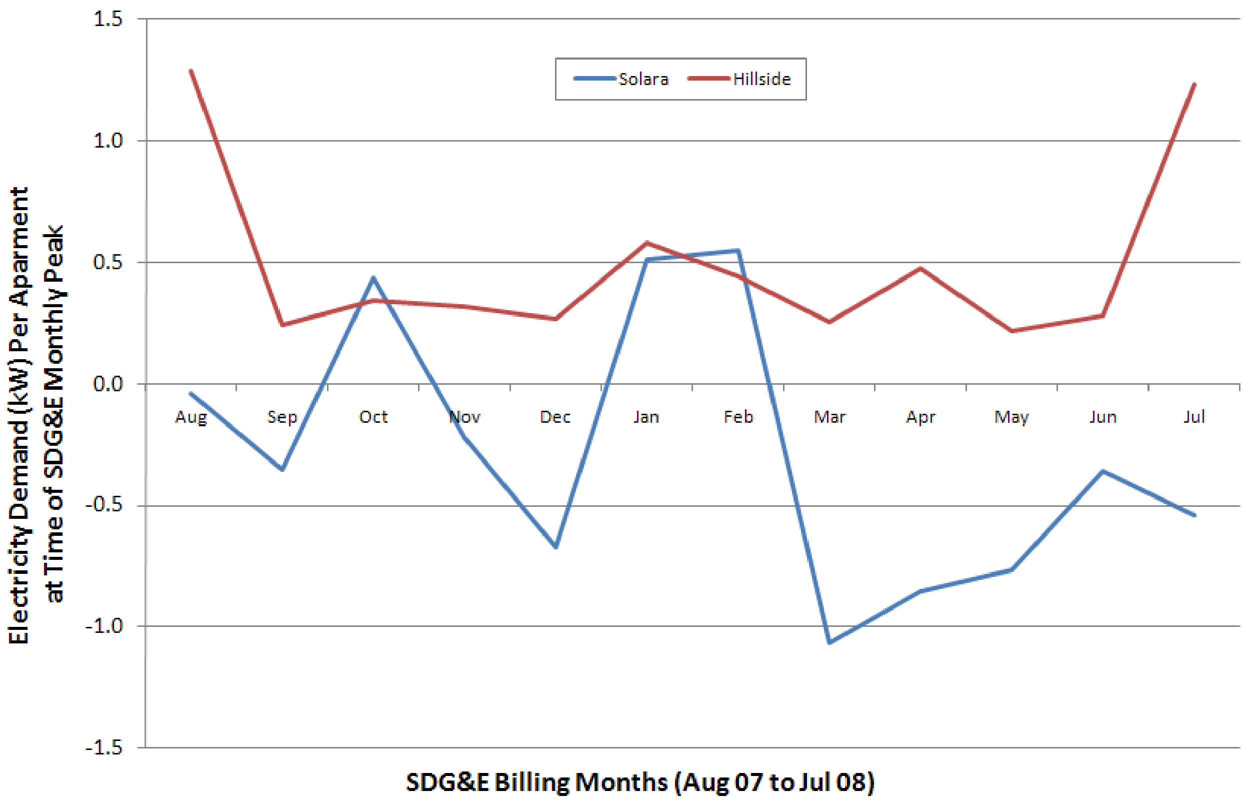
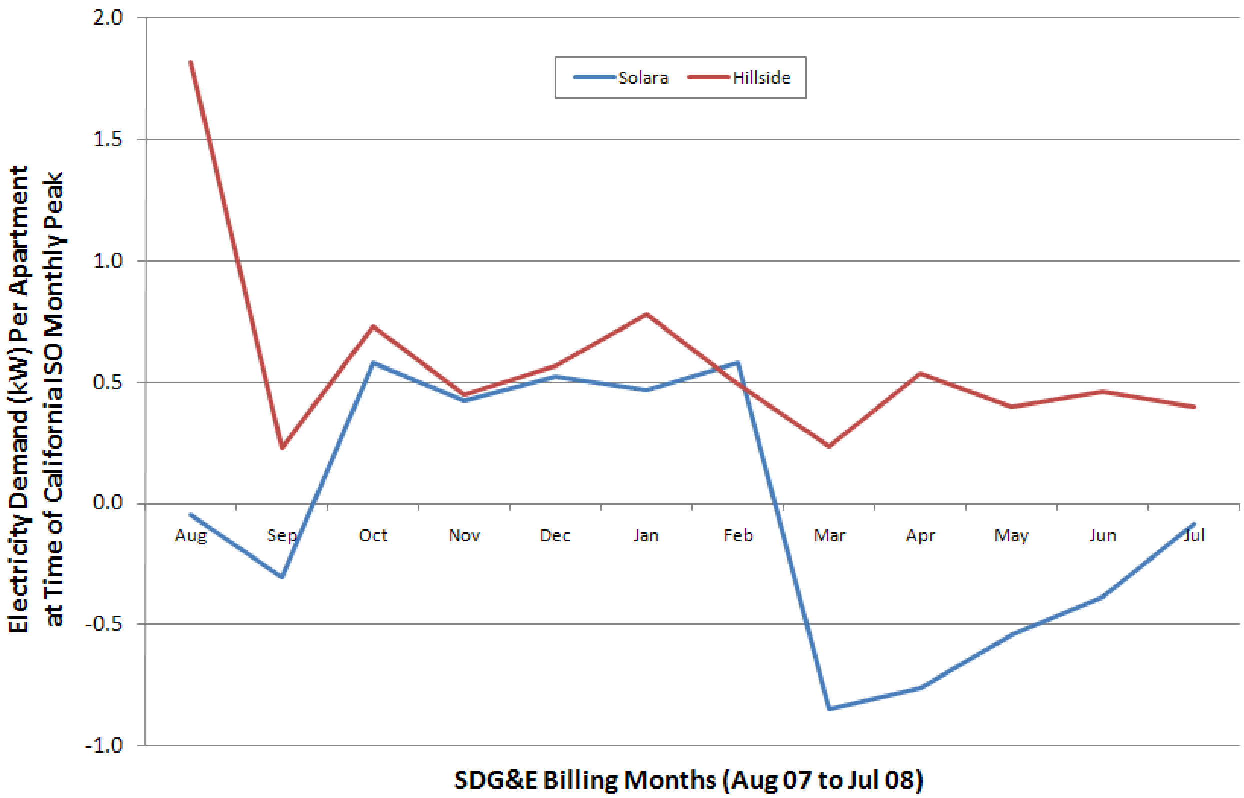


Figure 16. Electricity demand per apartment of Solara and Hillside at the time of the monthly San Diego Gas & Electric (SDG&E) demand peaks[17]

[17] The time of the monthly demand peak was provided to the project team by SDG&E; this time represents the single moment in time of the highest load experienced by the SDG&E grid during the billing cycle for each month. The Solara and Hillside demands were then evaluated at this moment in time. Note: Data shown are for the billing cycle month, which does not correspond directly to the calendar month.

As shown in Figure 17, the Solara apartments are on average net exporters of electricity at the time of the California ISO monthly demand peaks for more than half of the year, from March through September. Furthermore, the highest average demand at Solara during the California ISO's monthly demand peaks is just over 0.5 kW, compared with over 1.8 kW at Hillside.



5.0 Figure 17. Electricity demand per apartment of Solara and Hillside at the time of the monthly California ISO demand peaks[18]

[18] The time of the California ISO monthly demand peak was determined from publicly available data published on the California ISO OASIS website (http://oasis.caiso.com); this time represents the single moment in time of the highest load experienced by the California electricity grid during the billing cycle for each month. The Solara and Hillside demands were then evaluated at this moment in time. Note: Data shown are for the SDG&E billing cycle month, which does not correspond directly to the calendar month.

5.0 Conclusions and Recommendations

5.1 ZENH Goal Performance

For the August 2007 through July 2008 monitoring period analyzed in this report, Solara met the Zero Energy New Homes (ZENH) goal for summer peak demand below 1 kW. In fact, the 28 monitored Solara apartments were net exporters to the grid during the SDG&E peak demand period for nine out of twelve months. Moreover, at the time of the annual system peak in August 2007, the Solara apartments were exporting energy *back to the grid*. Based on these data, the design and operation of the Solara ZENH community significantly reduces grid congestion during the most critical peak demand periods of the year.

Due to differences in the billing structures and fuels used for cooking appliances, Solara did not meet the ZENH 70% electricity cost reduction goal when compared with Hillside. Because the residents are not paying the bills directly, they are not eligible for the same low income discounts being used in the baseline community, where the residents pay for their utilities directly. This increases the electricity costs, though not usage, by more than 20% for Solara. Had the two communities used the same billing rates, electric utility costs would have been reduced by more than 80% for Solara, well beyond the ZENH program goal of 70%. Additionally, the Solara apartments use electric appliances for cooking while the baseline community uses natural gas. If the estimated electricity consumption of the cooking appliances is excluded for Solara, electricity costs would be more than 80% below the baseline community, again well beyond the ZENH program goal.

5.2 Comparison with Modeled Performance

Because the community was designed and built to Title 24 2001 standards, the ZENH goal of a 25% reduction in time-dependent-valuation energy use with respect to Title 24 2005 was not achieved. The Solara apartments were designed to be approximately 40% better than 2001 Title 24 standards, which translates into approximately 12-15% better than 2005 standards (depending on orientation of the unit).

The energy model results predict that the Solara community should use approximately 8.5% less electricity than code-compliant construction. In operation, the Solara apartments were observed to consume more gross electricity (excluding PV production) than the baseline community, which could result from differences in cooking fuels, the fact that the baseline units were not minimally code compliant, or the behavioral effects of the different billing structures.

Adjusting for the use of electric cooking appliances, Solara consumes the same amount of normalized electricity as Hillside. Although this may imply the energy efficiency measures had no significant impact in reducing electricity consumption at Solara, the behavioral effects of the different utility billing structures, where Solara residents do not pay for electricity directly and Hillside residents do, may be skewing the results. Additionally, the baseline units were built to be approximately 28% above Title 24 energy code, making it difficult to evaluate the performance of the efficiency measures by comparison with Hillside.

5.3 Total Site Energy Use and Cost Performance

Although net electricity costs are reduced by more than 60% at Solara when compared with Hillside, total energy costs, including natural gas, are reduced by only 14% on a normalized basis. Both differences in billing structures and design contribute to this result. Solara has been on the incorrect natural gas rate structure for the past year, inflating natural gas costs by more than 25%. Additionally, because Solara residents do not pay natural gas bills directly, they are not eligible for the low income discounts available to the baseline community, further inflating the natural gas costs at Solara when compared with Hillside.

Also, the centralized hot water heating systems at Solara appear to result in significantly more natural gas consumption during the summer and spring months, greatly increasing the total utility costs to the community. This increase in natural gas use means that although net electricity consumption is reduced by 86% at Solara compared with Hillside, total net energy use (including both electricity and natural gas) was reduced only by 31%.

5.4 Design Implications for ZENH

There are numerous important design lessons learned from Solara that can inform future ZENH projects. While trying to achieve zero net electricity consumption, the inclusion of electric appliances has a significant impact on overall performance and necessary PV system size. Approximately 0.3 kW of installed PV capacity is needed to account for the projected loads of electric cooking appliances, at a cost of nearly $2500.[19] The utility billing rate structure also has a significant impact on ZENH performance. Residents who pay for their own utility bills are encouraged to conserve, helping to achieve ZENH energy and cost performance goals. Also, for low income housing, residents who pay their own electric bills are eligible for discounted rates, further reducing operational costs. Due to the influence Solara has had on future policies, this disadvantageous billing situation is highly unlikely to be repeated.

Significant deviations were observed in the energy consumption of apartments at Solara. For the monitoring period, there was nearly an order of magnitude difference in gross electricity consumption between the lowest and highest consumers on a per bedroom basis (see Figure 11**Figure 23**). Even after data was normalized by bedroom, which is a proxy for occupancy, variation in unit location and orientation cannot account for such large difference in gross consumption. Therefore, more research is needed not only to understand the effect of occupant behavior on consumption but also to understand how energy conservation can most effectively be promoted.

The design of heating systems can have a significant impact on overall ZENH energy performance. Centralized heating systems for apartments that cannot be disabled during the non-heating months should be avoided to reduce gas consumption. If centralized heating

[19] Based on cooking appliance consumption of 440kWh per year and annual PV production of 1,485 kWh per kW; installed PV system costs are assumed to be $8,000 per kW.

systems are used, they should be designed to respond to heating demand from the occupants such that they can be disabled when no demand exists for the majority of the year.

To truly achieve net zero energy performance, projects will either have to use electric-only utilities (no natural gas) or use on site solar thermal systems to provide domestic hot water and heating. This is because in most apartment configurations there is limited roof space to deploy both solar photovoltaics for electricity production and solar thermal panels to produce hot water.

5.5 Monitoring Equipment Performance

The performance of the off-the-shelf monitoring solutions used for the Solara Zero Energy New Homes Monitoring and Evaluation Project presented a number of challenges, both during installation and operation. As detailed in Appendix A, the inverter-integrated PV monitoring equipment was difficult to install, and the accompanying software for retrieving and archiving data was often unreliable. To avoid these types of complications, future studies should ensure that monitoring hardware and software, whether integrated or third party, are capable of delivering stable performance in the long term[20].

While the third party Dent Instruments ElitePro™ power meters were much easier to install and were more reliable, software and communications issues required some amount of time for manual data gathering throughout the year. In the future, more robust monitoring solutions are needed to ensure reliable sub-hourly performance data collection. More specifically, while the Dent Instruments monitoring hardware platform itself is robust, better software applications and data collection and communication protocols are needed to improve the reliability and reduce the costs of data collection.

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[20] Third party monitoring options were explored for the Solara projected, but were not deemed financially viable at the time.

5.6 Recommendations

A number of key recommendations can be drawn from the conclusions:

1. Research is needed to understand the impact of utility billing structures, feedback devices, and other strategies for influencing occupant behavior in order to cost effectively achieve ZENH program goals.
2. More performance data are needed over a longer monitoring window to substantiate the utility grid peak demand implications of ZENH projects. Extended performance monitoring may facilitate a revaluation of current incentive structures for solar PV and ZENH projects based on their contribution to local grid congestion reduction.
3. More research is needed to understand optimized net zero energy designs for affordable and multi-family housing that consider total site energy consumption, including both electricity and natural gas , in particular limitations to achieving zero net energy based on building form, height, and density.
4. While the apartment data collection systems used reliable hardware platforms, more research and development is needed for the supporting software systems that collect, organize, and display performance data.